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Assessment of Ethylenebisdithiocarbamate (EBDC) Fungicide Uses In Agriculture

USDA/State/EPA Assessment Team

Part I: An Analysis of Uses and Their Relationship to Exposure

by

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National Agricultural Pesticide Impact Assessment Program
United States Department of Agriculture

Coordinated by the Office of Environmental Quality Activities, USDA

December 15, 1977

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OVERALL SUMMARY AND CONCLUSIONS

The ethylenebisdithiocarbamates (EBDC's) are a class of fungicides which includes nabam, maneb, mancozeb, zineb, metiram, and diammonium EBDC. They provide control of a broad range of diseases such as blights, blotches, downy mildews, molds, rots, rusts, anthracnose and other fungus incited diseases. Their use amounts to about 22% of the fungicides used in the United States and 57% of the fungicides used in the world.

Since their introduction in the United States in the mid-1940's, major uses have been developed in all areas of agricultural crop production. The highest volume uses occur in vegetable crop disease control, especially potatoes and tomatoes. There are many uses of EBC's for which no acceptable alternatives exist. These uses often needed to continue production of 'minor' or 'speciality' crops.

Although a variety of fungicides have been developed since the introduction of the EBDC's, EBDC's continue to be widely used. This is because they are effective against a broad spectrum of pathogens on any given crop, they do not promote pathogen resistance to fungicides, they are relatively non-phytotoxic, and are inexpensive.

The detailed analysis of the benefits of use and the impact on agriculture in the event the EBDC's become unavailable will be discussed in part two of this assessment report. An overview of uses is given here relative to the analysis of EBDC and ETU residues in

the diet and to the discussion of the transformation of the materials in biological and nonbiological systems. An identification of data gaps and research needs to more critically evaluate the benefits of EBDC uses will also be made in our benefits analysis.

With respect to EBDC residue exposure levels, we find the calculated estimate of 0.000129 mg/kg of body weight is a more realistic value than the 0.0608 mg/kg estimate cited in the EPA EBDC RPAR notice. This value is well below the FAO/WHO recommended temporary acceptable daily intake of 0.005 mg/kg of body weight. Our calculated total ETU exposure including residues on crop surfaces and stoichiometric conversion from EBDC is 0.000059 mg/kg of body weight, much less than the estimate cited in the RPAR.

The basis for the difference between our estimates and the EPA's lies in our use of assumptions which more nearly reflect current agricultural production and consumer practices than those traditionally employed by EPA. In addition, certain redundancies entered into the EPA calculations on which the RPAR decision was based, have been eliminated here.

Exposure levels can be most accurately determined on the basis of residues found on fresh and processed food items from the retail market, and from fresh food items cooked before consumption.

Introduction

Definition and Some Chemical Properties of EBDC Fungicides

EBDC (ethylenebisdithiocarbamate) refers to a class of fungicides which includes nabam (Dithane D-14), maneb (Dithane M-22, Manzate), mancozeb (Dithane M-45, Manzate 200), zineb (Dithane Z-78), metiram (a mixture of Zinc NH_4 and ZnSDC) (Polyram), and diammonium EDBC (Amobam). Table 1 gives those names accepted for use in the ingredient statement on pesticide products as required by FIFRA regulations. Each is based on dithiocarbamic acid. They are used extensively in agriculture—on many fruits, vegetables and field crops, turfgrass, seeds, etc.—for the control of blights, blotches, mildews, molds, rots, rusts, and other fungus-incited diseases. There are 206 chemical companies listed as registrants in current EPA files. There are 876 products containing EBDC fungicides currently registered. Domestic producers include DuPont, FMC, Pennwalt, Roberts Chemical and Rohm and Haas. EBDC products are also manufactured in other countries and some are imported into the United States.

Zineb can be produced commercially by reaction of ethylenediamine (EDA) with CS_2 in the presence of alkali followed by precipitation of zineb with addition of zinc sulfate (IARC, 1976). Zineb can also be made, as is rarely done in the field, by mixing nabam or Amobam® with zinc sulfate (IARC, 1976). The preparation of

maneb is analogous to that of zineb that manganese sulfate is used in place of zinc sulfate for its precipitation (IARS, 1976). Mancozeb can be prepared from an aqueous slurry of maneb and a water-soluble zinc salt (U.S. Patent Office). Amobam® and nabam are also made by reaction of EDZ and CS_2 in the presence of either NH_3 to yield and diammonium EBDC or NaOH to yield the disodium EBDC (Melnikov, 1971). Metiram is made by reaction of EDA and CS_2 in the presence of zinc oxide and hydrogen peroxide (H_2O_2) or by oxidation of an aqueous solution of nabam with H_2O_2) followed by precipitation with zinc sulfate (Melnikov, 1971).

The chemistry of the EBDC's is complicated by their instability and their propensity to form polymers, especially in the presence of certain ubiquitous metallic ions. They are subject to a manifold degradation which begins with production and continues with storage and application (Engst and Schnaak, 1974). Important factors influencing chemical degradation are presence of oxygen, humidity, temp~~a~~erature, and pH (Engst and Schaak, 1974). A number of common degradation products have been identified and will be discussed later in this report. While all of these and other degradation products can result from EBDC degradation, the relative proportions of them do appear to be different for the individual EBDC's. Ethylenethiourea (ETU) appears to be the dominant degradation product of zineb, whereas nabam and maneb yield a larger proportion of ethylenebisdiisothiocyanato sulfide (EBIS) (Engst and Schnaak, 1974).

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Summary of Points Triggering a Rebuttable Presumption Against Reregistration

The purpose of this report is to analyze the exposure risks to EBDC fungicides. According to a study by the U.S. Environmental Protection Agency, the following adverse effects of EBDC's meet or exceed the criteria for issuance of a rebuttable presumption against registration (RPAR).

A. Hazard to Wildlife: Aquatic Organisms

Section 162.11(a)(3)(i)(B)(3) specifies that a rebuttable presumption shall arise against pesticide's use for direct application to water if such use would result in concentrations in a 6-inch layer of water more than one-half the acute LC_{50} for aquatic organisms likely to be exposed. Data appear to indicate that pesticide products containing maneb or zineb labelled for use against cranberry fruit rot at an application rate of up to 6 pounds active ingredient per acre may exceed these criteria.

B. Oncogenic Effects in Test Animals

40 CFR Section 162.11(a)(3)(ii)(A) provides that a rebuttable presumption shall arise if a pesticide's ingredient(s), metabolite(s), or degradation product(s) induce(s) "oncogenic effects in experimental mammalian species or in man as a result of oral, inhalation or dermal exposure." 40 CFR Section 162.3 (bb)

defines the term "oncogenic" as "the Property of a substance or a mixture of substances to produce or induce benign or malignant tumor formation in living animals." The EPA Carcinogen Assessment Group (CAG) has reviewed the studies and concluded that "oral administration of maneb significantly increased the incidence of benign tumors of the lung in one strain of mouse" (Albert, 1977).

ETU, a degradation product and metabolite common to all the EBDC's, is oncogenic in mice and rats. CAG concluded that ETU "induced highly significant incidences of tumors of the liver in males and females of mice. There also were significant increases in tumors at all sites, but this was essentially due to the increases in liver tumors" (Albert, 1977).

CAG also concluded that ETU "increased significantly the frequency of thyroid cancers in two different studies on rats" (Albert, 1977).

On the basis of five studies, the Working Group of EPA concluded that the evidence that long-term oral administation of EBDC's or ETU is oncogenic in mice and rats supports the issuance of an RPAR.

C. <u>Teratogenic Effects in Test Animals</u>

40 CFR Section 162.11(a)(3)(ii)(B) provides that "A rebuttable presumption shall arise if a pesticide's ingredient(s),

metabolite(s), or degradation product(s) produces any other chronic or delayed toxic effect in test animals at any dosage up to a level, as determined by the Administrator, which is substantially higher than that to which humans can reasonably be anticipated to be exposed, taking into account ample margins of safety."

In determining whether an ample margin of safety exists to protect humans from teratogenic effects of ETU, the Working Group took into account the following factors:

(1) Tolerances exist for EBDC's on many different crops.

(2) EBDC's are converted to ETU with cooking.

(3) There are few data concerning actual intake of EBDC's or ETU in food.

The Working Group, therefore, determined that a reasonable approach is to assume that there is stoichiometric conversion of EBDC's to ETU and that the best estimate of daily intake is given by calculation of theoretical daily intake from existing EBDC tolerances. If the EBDC residues are assumed to be at tolerance levels and food factors established by FDA (Lehman, 1962) are used, the theoretical daily human intake of ETU is calculated as 0.02 mg/kg (Beach and Weaner, 1977). If the teratogenic NEL established by Khera (5 mg/kg body weight) is used, the resulting margin of safety is 250 (Beach and Weaner, 1977. The Working Group concludes that the margin of safety is not great enough to protect the population from the teratogenic effects of ETU, and that an RPAR be issued.

The Working Group is further concerned that the theoretical daily intake of EBDC's (0.06 mg/kg) exceeds the acceptable daily EBDC intake recommended by FAO/WHO (0.005. mg/kg) by a factor of 12.

History of EBDC Fungicides

Up to the late 1930's inorganic fungicides were the only materials widely available to the grower for the protection of agricultural crops from fungal diseases. Of these, Bordeaux mixture, a combination of copper sulfate and lime, was the most versatile. It was widely used since its discovery in 1882 by Millardet in France. It replaced the old sulfur standard on many crops.

However, Bordeaux mixture suffered several problems. First, it was phytotoxic to the plants on which it was used at the application rates needed for fungicidal activity. It had a corrosive effect on the grower's spray equipment and frequently clogged nozzles. It was difficult to make up, because it entailed rather precise mixing of copper and lime in the spray tank. Finally, it left a heavy and noticable residue on plant surfaces.

Aside from the copper compounds, the only other fungicides available in the early 1940's were lime-sulfur, sulfur dust, and the wettable sulfurs which were used on fruit and vegetable crops for scab and crown rot and powdery mildews, and inorganic mercurial

compounds which were used in the seed treatment of grain. Sulfur is still widely used today, especially to control powdery mildews.

Because of World War II, which placed a high priority on copper and mercury, there appeared a great demand for adequate substitute fungicides. The first derivative of a dithiocarbamate to achieve prominence was tetramethyithiuram disulfide, later called thiram. Next came the metal salts of dithiocarbamic acid.

The first reports of the metal salts of dithiocarbamic acid as successful field fungicides appeared in 1942 (Anderson, 1942; Kincaid, 1942) when it was reported that ferric dimethyldithiocarbamate (ferbam) successfully controlled downy mildew on tobacco on seed beds. In comparison with the old recommendations of 12-16 lbs of sulfur per 100 gallons of spray, the use of ferbam at 1-1/2 lb per 100 gallons seemed strikingly effective. Its potential for crop injury was much less than that of the copper sprays or sulfur, although it left an unsightly black residue on plant surfaces.

The promising control of early blight and anthracnose on tomatoes and early blight on potatoes achieved with zinc dimethyldithiocarbamate (ziram) was reported in 1944 (Heuberger and Wolfenbarger, 1944; Wilson, 1944).

Disodium ethylenebisdithiocarbamate (nabam) appeared in 1943 (Dimond, et al., 1943). Instability of nabam was a problem until the stabilizing effect of adding zinc sulfate to the spray tank was

discovered. From then on its progress was rapid, and it became widely used for many vegetable diseases. The next step naturally followed - the manufacture of zinc ethylenebisdithiocarbamate itself, known as zineb. It became commercially available in the mid 1940's and was eventually developed for use on approxomately 65 crops for 416 diseases.

In 1956 manganese ethylenebisdithiocarbamate was field testea on potatoes and later on other vegetable crops. It became known as maneb. It was introduced commercially in the early 1950's. It was similar to zineb in its effectiveness as a fungicidal agent on a number of crops, and better than zineb on many others. It is currently registered for use on 72 crops for 420 diseases. Included are many vegetables, fruits, ornamentals, and seed treatments.

In the early sixties a coordinated complex of the zinc and manganese salts of ethylenebisdithiocarbamate, named mancozeb, was introduced. It represented an even further improvement in the evolution of EBDC's, combining many of the benefits of zineb and maneb in one product. It is now labelled for use on 51 crops for 268 diseases. In addition, it is being tested in many instances for additional uses for which presently available materials are inadequate or for which no other material is labelled for use. Many of these label expansion projects involve "minor or specialty" crops such as ornamentals, tropical fruits, and vegetables. Also many projects are under way involving use of EBDC in combination with another fungicide.

General Qualities and Usefulness of EBDC's

In four years, from the time of its introduction in the mid 1940's, zineb replaced Bordeaux mixture as the standard fungicide on many crops in the United States. Within several more years the EBDC's had replaced Bordeaux, except in special situations, throughout the world. Why did this rapid and wide acceptance of EBDC's occur? Recent compilations by several companies give sales figures of about 27,000,000 lbs in the United States (and 255,000,000 lbs worldwide). This is out of a total of 119 million lbs of fungicides sold in the United States and 460 million lbs sold in the world. Such tremendous acceptance occurred because the EBDC's provided the growers for the first time with a good broad spectrum fungicide with no significant phytotoxic side effects. In addition, Powell and Shurtleff stated that the importance of this group of fungicides is emphasized by the fact that they controlled fungi that heretofore had not been effectively controlled by sulfur or copper compounds (1976). The rust diseases on fruits or ornamentals are good examples. Also, later chapters of this report will show that diseases caused by _Botrytis_, _Septoria_, and _Alternatia_ fungi and several anthracnose diseases were more adequately controlled.

For example, the production of potatoes, the most important vegetable in the world, has been increased dramatically since the introduction of EBDC fungicides. While it took the first 45 years of this century to increase the potato yield in the United States some 30% (from 91.8 bu/acre in the period 1901-1905 to 140.9 bu/acre

in the period 1941-1945), potato yields increased almost 90% in the next nine years (to 268 bu/acre by 1954), (McNew, 1959). EBDC's, along with the introduction of organic insecticides, improved spraying techniques, and new fertilizers had a hand in this increase.

Whereas all of these factors contributed to increased yields, EBDC's may well be the largest single factor. For instance, Heuberger and Manns (1943) reported in a test in Delaware with Dakota Red potatoes a 21% yield gain for nabam (Dithane D-14) plus $ZnSO_4$ plus lime, as compared with the use of Bordeaux mixture (the standard fungicide up to that time). Later on, Heuberger (1946) reported a 32% yield increase on potatoes grown in Delaware and treated with Dithane Z-78 (zineb).

Heuberger (1967) found in the mid 1940's that EBDC's gave control superior to copper compounds on tomatoes for all five of the common diseases -- the eartly blight, Stemphylium leaf spot, anthracnose, Septoria leaf spot, and late blight. The EBDC's also increase yields 2-3 tons per acre was a big yield. Yield increases were also reported on cucurbits (25% or more) and celery. Yield increase studies were also conducted by researchers on many crops including apples, corn, small grains, bananas, peanuts, and ornamentals.

There are no commercial fungicides which have as broad a target spectrum on as many crops as those in the EBDC class. There are substitutes for particular uses on particular commodities, but they

are often ineffective, more costly, or have more undesirable properties than the EBDC products.

EBDC's are compatible with most pesticides. This is important when incorporating them in total pest management--or integrated pest management--programs. For instance, in apple production the EBDC's are compatible with spray oils, are compatible with miticides, but are not toxic to the natural predators of the apple mite.

Finally, EBDC's are useful to combat the plant pathogens that are devloping resistance to many of our more specific fungicides. Again, apple protection can serve as an example, where the apple scab fungus has become resistant to other fungicides in many areas. As integrated pest management programs increase in use, the need for growers to use a general fungicide to quickly avert problems due to pathogen resistance will be ever more important.

Overview of Uses

Introduction

The EBDC fungicides have been in use for nearly 30 years. Throughout this period, continued research has resulted in more and more uses constantly being added to existing labels. Our examination of current EPA microfische files indicates that combined totals of all six EBDC compounds amount to 271 crop registrations for 1,296 diseases, divided up among 876 different products registered by 206 different companies (Table 1)!

Because of this extremely diverse and large registered use and product situation, it has been difficult for our assessment team to determine total production and use pictures for the United States. According to Farm Chemical Magazine (September, 1977), dithiocarbamate fungicides accounted for $50 million of a total $116 million U.S. fungicide market for 1974. Chemical and Engineering News of September 5, 1977, states that this market is growing by 7.3% per year. Thus, in 1977 the market would be about $61.75 million. Using this and other confidential sales information, the assessment team estimates that about 27 million pounds of EBDC fungicides are currently being used in this country each year. Our further benefits analysis may change this figure as more inmformation becomes available.

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Whereas detailed benefits and use information is still being gathered, a brief overview of uses is necessary to more adequately understand the perspective of potential exposure of the general population by the ingestion of EBDC and/or ETU residues. Since registrations occur in almost all areas of agriculture/commodity groupings, a commodity oriented overview will be presented.

There are several problems with this sort of an overview that could result in misinterpretation of the use situation. For instance, there are many uses of EBDC products on so-called "minor" or "speciality" crops. Loss of the uses would be quite serious, for manufacturers will likely be unwilling to go through the lengthy testing and registration process for a new product which would be sold only in small quantities. An example is the registration of zineb for the control of pathogenic fungi on mushrooms.

Furthermore, generalized usage pictures do not adequately take into account regionalization. For instance, mancozeb is considered essential on grapes in Missouri because of downy mildew. Areas without downy mildew, such as the large grape producing States of California or New York, do not list mancozeb as an essential use. Again, this creates a "minor" use, but here it is on a major crop.

Generalized use overviews do not bring out the fact that minor disease problems often become major because of shifts in crops varieties, cultural practices, climatic or weather changes, genetic changes in virulence of pathogens or in resistnce of pathogens to

fungicides. In some years, only 10% of the lettuce acreage in New Mexico may be treated with EBDC fungicides. However, 100% of the acreage may be treated in some years in order to protect the crop from downy mildew! A realistic estimate of year to year use on lettuce is 25% of the acreages.

The potential for the occurrence of new diseases or new, more virulent, pathogens is always present. In the early 1970's, maneb was used selectively in the northern corn belt states to prevent leaf blight. Recent years have not been identified as heavy maneb using years on northern grown corn. In this case, use was triggered by the sudden occurrence of a new strain of the southern corn leaf blight fungus. This fungus strain spread northward and attacked previously resistant corn varieties which necessitated the use of maneb. In a few years, growers shifted to varieties of corn resistant to the new strain and the crisis was over.

Vegetables

Most of the major EBDC uses occur in the area of vegetable production. In 1975, it was estimated that uses of dithiocarbamates (of which 91% are EBDC's) covered 43% of the vegetable market even though they represented only about 20% of the total fungicide market for agricultural uses (Chemical and Engineering News, September 5, 1977). Table 3 lists the vegetable registrations for the EBDC fungicides (35 crops and 163 diseases). Use estimates on a national basis are 7 million pounds of EBDC fungicide per year on an average of 50%

of the potato acreage, 3.6 million lbs on 25% of the tomato acreage, and 7 - 9 million lbs of EBDC fungicides used on other vegetables.

Our team has estimated that about 353 million cwt. of potatoes were produced on about 1.4 million acres in 1976. Thirty-two percent of this acreage was east of the Mississippi River and 68% was in the western United States. The results of our survey of potato extension specialists indicated that about 72% of the acreage east of the Mississippi River was sprayed with an EBDC fungicide (primarily mancozeb), amounting to about 4 million pounds. In the west, abvout 50% of the acreage is currently sprayed with about 1.5 million lbs of mancozeb. Across the country, 50 - 60% of the potato seed pieces are treated with EBDC's, generally as an 8% mancozeb dust.

This EBDC potato usage protects the crop from two major foliar diseases, *Phytophthora* late blight and *Alternaria* early blight. Both of these diseases can occur anywhere in the country depending on weather; however, late blight is usually more severe in the East and early blight is a dangerous Western potato disease. Fungicidal sprays are also suggested for control of *Botrytis* leaf spot and vine rot. Fungicide seed piece decay, *Rhizoctonia* stem canker, common scab, *Verticillium* wilt, and other pathogens that may be carried on the seed tubers.

The EBDC fungicides are effective in controlling a number of foliar and fruit diseases of tomatoes. The more important diseases

are: (1) anthracnose, (2) early blight, (3) late blight, (4) gray leaf spot, and (5) Septoria leaf blight. Control of these diseases can increse yields 20 to 30% in the northestern states and up to 60% in Florida. It is estimated that the major northern tomato producing states used over 500,000 pounds of EBDC fungicides on approximately 35,000 acres in 1977. In Florida, about 1.8 million lbs of EBDC's were used to protect the crop from early blight and late blight in 37,795 acres. For Florida growers, early blight is a persistant disease occurring every season. Since up to 32 applications per year must be made, EBDC (primarily maneb) is the material of choice because it is cheaper than other products. In California, extensive tomato acreage of over 247,000 acres is primarily devoted to processing tomatoes. Disease severity is less there, and only about 11% of the sprayed acreage is treated with EBDC's to control black mold, early blight, and Botrytis mold.

The most widespread use of EBDC fungicides to protect other vegetable crops from disease occurs in Florida where 5.8 million lbs are used mostly on celery, cucumber, peppers, snap beans, squash, sweet corn, and watermelon. Downy mildew is a serious disease of lima beans in the mid-Atlantic area. Maneb is the only effective fungicide registered on this crop. Downy mildew and Botryis gray mold are diseases of lettuce in California for which 40% of the 159,956 acres planted was protected with EBDC fungicides. EBDC's are also used in moderate amounts in the western states on cucurbits, onions, carrots, celery, broccoli, spinach, cauliflower, and cabbage. Another western use of EBDC's is for downy mildew

control on hops. This only represents 44,000 lbs of EBDC on 8500 acres, but it is an essential use to control a serious disease.

Fruits

Our assessment team estimates that about 4.2 million lbs of EBDC fungicides are used on fruits for the 75 diseases on the 24 crops listed in Table 3. The majority of the use is on apples, where EBDC's are registered for control of 19 diseases. In the northern states, apple scab is the major disease. Scab, powdery mildew, rusts, and fruit rots are the diseases most commonly found in the mid-Atlantic and mid-Western states. EBDC's are preferred here because of economical broad spectrum control, acceptable fruit finish, and compatibility with dinocap for powdery mildew control. EBDC's are well suited to integrated mite control programs in these areas because of safety to the beetle predator and predatory mites. They are also compatible with spray oils. In the Southeastern states, major apple disease problems are fruit rots, scab, rust, and powdery mildew. In some southern areas, EBDC's are the only materials presently available to control the fruit rots. In all areas, EBDC's are relied upon to control strains of the apple scab fungus which have become resistant to alternative fungicides, mainly benomyl and dodine. Up to 90% of the apple acreage in some eastern states may be treated with EBDC's, but very little western apple acreage is treated.

Information on other EBDC fruit uses is still being gathered. Important uses appear to be for black knot control on plums and prunes in the Northeast, peach rust in South Carolina, fruit rot on grapes in the Southeast, and for diseases of pears, raspberries, and cranberries.

Field Crops

About 2 million pounds of EBDC fungicides are used on the wheat and barley cereal crops in the United States each year. These are used for foliar disease protection (0.7 million lbs) and for seed treatment (1.2 million lbs). Seed treatment is the practice of using a fungicide coating of the seed to protect the seed from invasion by fungi and bacteria which results in damping-off or seedling blight. The use of EBDC's as a seed treatment is largely confined to the States of Montana, North Dakota, South Dakota, and Minnesota, where wheat seed treatment has resulted in 4.1 bushels per acre of increased yield because of an increased plant stand of 26.9%. Additionally, over 1 million acres of winter wheat in Indiana and Kansas are planted to EBDC treated seed.

EBDC fungicides are beginning to be used to protect cereal crops from diseases such as leaf rust, Septroia leaf blotch, net blotch, spot blotch, and brown spot. The acreage treated varies from year to year depending on the crop value. In 1975, Minnesota farmers treated about 1 million acres. In 1976, more than 400,000 acres of winter wheat were treated in Missouri. North Dakota

research on wheat has demonstrated 28% yield increases over 4 years of test results with EBDC spray programs.

Other field crops on which EBDC's are used include cotton for rust control in Arizona. This is a locally serious disease for which there are no alternative fungicides. EBDC fungicides are used extensively in the peanut disease control programs in North Carolina, Oklahoma, Texas, and Virginia. Approximately 3 million lbs were applied to about 275,000 acres in 1977. In Minnesota, EBDC's are essential to control Helminthosporium leaf spot on the 23,000 acres of wild rice grown in that State each year.

Mushrooms

In the United States, mushrooms are produced on 117.7 million square feet of commercial beds (2737 "acres"), primarily in California and Pennsylvania. Zineb is applied to more than 60% of the beds to control Verticillium dry bubble and other fungus diseases which spot the mushrooms. There is no viable alternative material available for these uses on this high value crop.

Turf

Turfgrasses have become the major ground cover plants for most of the suburban and urban United States. Rising quality standards in recent years have contributed to the importance of disease control. Table 4 lists the uses of EBDC fungicides in this area.

There are hundreds of products labelled for turf disease control that contain one of these EBDC fungicides. Grass seed production also involves use of these compounds.

Important diseases of turfgrasses that EBDC's are used for include the Helminthosporium leaf spots and melting outs (declines), Rhizoctonia blight or brown patch, and Pythium seedling diseases and blight. Our team estimates that at least 0.65 million lbs of EBDC's (primarily maneb) are used to control these diseses. They are preferred because of their low cost and wide availability. Additionally, they are used to combat the fungicide resistance to alternatives that is now appearing in many areas.

Ornamentals

Tables 5 and 6 list some uses of EBDC fungicides for diseases of ornamental plants. A most significant part of the EBDC fungicide use picture in ornamentals is that they can be used to counter the myriad of severe but minor disease problems that may occur in a nursery, greenhouse, or ornamental planting, even though specific plant/disease labelling may be lacking. As in turf, total use estimates are difficult because of the many products on the market.

Most commercial use of EBDC's on ornamentals is in Florida, where mancozeb is used to control many diseases of foliage plants. Much of the chrysanthemum acreage in Florida is also sprayed with EBDC's. Other flower crops in which EBDC's are used include

gladiolus, carnations, and bulb crops (tulips, lilies, etc.). On woody plants, zineb appears to be the most widely used EBDC, with mancozeb use increasing. Azaleas, camellias, crabapples, and roses are examples of commonly treated crops.

Forest Products

The forest industry does not consider it economically feasible to apply protectant fungicides to forest stands. The largest quantity of EBDC fungicide use on a forest product is nabam as a slimicide in the wet end of pulp and paper mills. Precise use figures are not available. Total slimicide use (all fungicide) is around 4 million lbs.

About 150,000 lbs of maneb were used to control needle cast of Christmas trees in 10,000 acres of plantings in the Lake States. A very small amount of maneb is used to control *Herpobasidium* blight of honeysuckle in windbreak plantings in the Plains States. Finally, about 4,000 acres of tree seedling nurseries are treated with maneb to control needle casts, anthracnose, and leaf spot diseases. Since regeneration of the nation's forests depend upon nursery tree production, such a use is more important than may be realized with casual analysis.

World Use Overview

Although the purpose of this report is to discuss usage of EBDC fungicides with respect to their use in the United States, a brief discussion of worldwide use patterns is necessary for a complete analysis of benefits and risks. The reregistration actions taken by our country will have an impact on agencies in other lands. Nations with less sophisticated risk/benefit analysis mechanisms may not be able to interpret our country's decision if ours are made without any regard to world use patterns.

Whereas we use 25 - 27 million lbs of EBDC fungicides annually in the United States, world use has been estimated at 255 million lbs (1975 figures). Table 8 lists the major use categories and the volumes used that we have estimated for 1975. A major difference between world usage and United States usage in relative importance of use categories is the use of EBDC's on grapes, largely a European use to control downy mildew. Another notable use is that on bananas, where maneb and benomyl are essential to control Sigatoka disease. World use patterns on vegetables and other fruits follow closely those in this country.

Summary and Conclusions

1. Since their introduction in the mid-1940's EBDC fungicides have become the most widely used disese control chemicals in the production of food in the United States and in the World.

2. Major agricultural uses in the United States are in the production of potatoes, tomatoes, other vegetables, apples, and certain cereal grains.

3. Many small volume uses exist for which there are no adequate alternatives. These occur on "speciality" or "minor" crops as well as major crops.

4. EBDC uses are desirable because the fungicides have broad spectrums of activities, do not promote pathogen resistance, are relatively non-phytotoxic, and are inexpensive.

5. A detailed analysis of the benefits of uses will be presented in part two of our assessment report.

Table 1. EBDC Nomenclature
(Source: EPA Position Document 1 on Ethylenebisdithiocarbamates)

Common Name	Label Chemical Name	Trade Name(s)	CAS Name	CAS Number
1. None	Diammonium EBDC	Amobam®	Carbamodithioic acid, 1,2-ethanediylbis-, diammonium salt	3566-10-7
2. Mancozeb*	**	Dithane® M-45 Manzate® 200	[[1,2-Ethanediylbis [carbamodithioato]] (2-)]manganese mixture with [[1,2-ethanediylbis [carbamodithioato]] (2-)]zinc	8018-01-7
3. Maneb	Manganese EBDC	Manzate® Dithane® M-22	[[1,2-Ethanediylbis [carbamodithioate] (2-)]manganese	12427-38-2
4. Nabam	Disodium EBDC	Parzate® Dithane® D-14	Disodium 1,2-ethane-diylbis[carbamodithioate]	142-59-6
5. Metiram*	***	Polyram®	Metiram	
6. Zineb	Zinc EBDC	Dithane® Z-78	[[1,2-Ethanediylbis [carbamodithioato]] (2-)]zinc	12122-67-7

* Recognized in Europe but not yet established in the United States. These names will be used in this document for convenience.

** Zinc ion and manganese ethylene bisdithiocarbamate 80%, a coordination product of manganese 16%, zinc 2%, ethylene bisdithiocarbamate 62%.

*** Mixture of 5.2 parts by weight (89.9%) of ammoniates of [ethylenebis(dithiocarbamatgo)]zinc with 1 part by weight (16.1%) ethylenebis[dithiocarbamic acid], bimolecular and trimolecular cyclic anhydrosulfides and disulfides.

Table 2. Total registrations and product summary for EBDC fungicides.

Chemical	Crop Registrations	Number of Diseases	Number of Products*
Diammonium EBDC	21	47	2
Nabam	44	104	51
Mancozeb	51	268	110
Maneb	72	420	306
Zineb	65	416	354
Metiram	18	41	53
Totals	271	1296	876

*Number of separately labelled proprietary formulations, including those containing EBDC's alone or in combination with other pesticides.

Table 3. EBDC Fungicides Registered for Control of Diseases of Vegetables*

Plant	Disease	Registered EBDC
Asparagus	Crown rot	Mancozeb
	Rust	Mancozeb Maneb Polyram Zineb
Beans (field & snap)	Angular leaf spot	Zineb
	Anthracnose	Maneb Zineb
	Downy mildew	Maneb Zineb
	Downy mildew	Maneb
	Rust	Maneb Zineb
Beans (lima)	Anthracnose	Maneb Zineb
	Downy mildew	Maneb Zineb
	Rust	Zineb
Beets	Cercospora leaf spot	Zineb
	Downy mildew	Zineb
	Leaf spots	Zineb
	Seed treatment	Zineb
Blackeyed beans	Rust	Maneb
Broccoli	Alternaria leaf spot	Maneb
	Downy mildew	Maneb Zineb
	Leaf spots	Zineb

*Based on EPA microfische label and registration files.

Plant	Disease	Registered EBDC
Brussels sprouts	Alternaria leaf spot	Maneb
	Downy mildew	Maneb Zineb
	Leaf spot	Zineb
Cabbage	Alternaria leaf spot	Maneb
	Downy mildew	Maneb Zineb
	Leaf spots	Zineb
Cantaloupe	Alternaria leaf spot	Zineb
	Angular leaf spot	Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Cercospora leaf spot	Maneb
	Downy mildew	Mancozeb Maneb Polyram Zineb
	Gummy stem blight	Mancozeb Maneb Polyram Zineb
	Scab	Mancozeb
Carrot	Alternaria blight	Maneb Zineb
	Cercospora blight	Mancozeb Maneb Zineb

Plant	Disease	Registered EBDC
Cassaba melon	Alternaria leaf spot (blight)	Zineb
	Angular leaf spot	Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Cercospora leaf spot	Mancozeb Maneb
	Downy mildew	Mancozeb Maneb Zineb
	Gummy stem blight	Mancozeb Maneb Zineb
	Scab	Mancozeb Zineb
Cauliflower	Alternaria leaf spot	Maneb
	Downy mildew	Maneb Zineb
	Leaf spot	Zineb
Celery	Early blight and late blight (Cercospora and Septoria)	Mancozeb Maneb Polyram Zineb
Chinese cabbage	Downy mildew	Zineb
	Leaf spot	Zineb
Collards	Alternaria spot	Maneb
	Downy mildew	Maneb Zineb
	Leaf spot	Zineb

Plant	Disease	Registered EBDC
Corn (sweet)	Helminthosporium leaf blight	Mancozeb Maneb Polyram
Crenshaw melons	Alternaria leaf blight	Mancozeb Zineb
	Angular leaf spot	Zineb
	Anthracnose	Maneb Zineb
	Blossom blight	Zineb
	Cercospora leaf spot	Mancozeb Maneb
	Downy mildew	Mancozeb Maneb Zineb
	Gummy stem blight	Mancozeb Maneb Zineb
	Scab	Mancozeb Zineb
Cucumber	Alternaria leaf spot	Mancozeb Maneb Polyram Zineb
	Angular leaf spot	Maneb Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Downy mildew	Mancozeb Maneb Polyram Zineb
	Fruit rots	Maneb

Plant	Disease	Registered EBDC
Cucumber (cont'd.)	Gummy stem blight	Mancozeb Polyram Zineb
	Scab	Mancozeb Zineb
Eggplant	Anthracnose	Maneb Zineb
	Cercospora leaf spot	Zineb
	Downy mildew	Zineb
	Early blight (Alternaria)	Maneb Zineb
	Fruit rots	Zineb
	Late blight (Phytophthora)	Zineb
	Phomopsis	Maneb Zineb
Honeydew melons	Alternaria blight	Mancozeb Zineb
	Angular leaf spot	Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Cercospora leaf spot	Mancozeb Maneb
	Downy mildew	Mancozeb Maneb Zineb
	Gummy stem blight	Mancozeb Maneb Zineb
	Scab	Mancozeb Zineb

Plant	Disease	Registered EBDC
Kale	Alternaria	Maneb
	Downy mildew	Maneb Zineb
	Leaf spot	Zineb
Lettuce	Botrytis blight and rot	Zineb
	Downy mildew	Maneb Zineb
Persian melon	Alternaria blight	Mancozeb Zineb
	Angular leaf spot	Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Cercospora leaf spot	Mancozeb Maneb
	Downy mildew	Mancozeb Maneb Zineb
	Gummy stem blight	Mancozeb Maneb Zineb
	Leaf spot	Mancozeb Maneb
	Scab	Zineb
Mushroom	Brown spot (Verticillium)	Zineb
	Cobweb (Dactylium)	Zineb
	Mildew	Zineb
	Soft rot	Zineb

Plant	Disease	Registered EBDC
Muskmelon	Alternaria leaf spot	Mancozeb Zineb
	Angular leaf spot	Zineb
	Anthraconose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Cercospora leaf spot	Mancozeb Maneb
	Downy mildew	Mancozeb Maneb
	Gummy stem blight	Mancozeb Maneb Zineb
	Scab	Zineb
Onion	Botrytis blight and neck rot	Mancozeb Maneb Zineb
	Downy mildew	Mancozeb Maneb Zineb
	Neck rot	Mancozeb
	Purple blotch	Mancozeb Maneb Zineb
	Smut	Mancozeb
Peas	Damping off	Zineb
	Downy mildew	Zineb
	Rust	Zineb
Potato	Early blight	Mancozeb Maneb Polyram
	Late blight	Mancozeb Maneb Polyram

Plant	Disease	Registered EBDC
Potato (cont'd.)	Scab	Mancozeb Polyram
	Seed piece treatment	Mancozeb Zineb
Pumpkin	Alternaria blight	Zineb
	Angular leaf spot	Maneb Zineb
	Anthracnose	Zineb
	Bacterial wilt	Zineb
	Downy mildew	Maneb Zineb
	Gummy stem blight	Zineb
	Scab	Zineb
Radish	Alternaria leaf spot	Zineb
	Downy mildew	Zineb
	Leaf spots	Zineb
Spinach	Anthracnose	Maneb Zineb
	Cercospora leaf spot	Maneb Zineb
	Downy mildew	Maneb Zineb
	White rust	Maneb
Squash	Alternaria leaf spot	Mancozeb Zineb
	Angular leaf spot	Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Cercospora leaf spot	Mancozeb

Plant	Disease	Registered EBDC
Squash (cont'd.)	Downy mildew	Mancozeb Maneb Zineb
	Gummy stem blight	Mancozeb Zineb
	Pythium fruit rot	Maneb
	Scab	Mancozeb Zineb
Tomato	Anthracnose	Mancozeb Polyram Zineb
	Bacterial spot	Mancozeb Maneb
	Black mold (Alternaria	Mancozeb
	Early blight	Mancozeb Maneb Polyram Zineb
	Gray leaf spot (Stemphylium)	Maneb Polyram
	Gray leaf mold	Mancozeb Zineb
	Late blight	Mancozeb Maneb Polyram Zineb
	Nailhead spot	Zineb
	Septoria leaf spot	Maneb Zineb
	Southern blight	Zineb
Turnip	Downy mildew	Maneb Zineb
	Leaf spots	Maneb Zineb

Plant	Disease	Registered EBDC
Watermelon	Alternaria leaf spot	Mancozeb Maneb
	Angular leaf spot	Zineb
	Anthracnose	Mancozeb Maneb Zineb
	Blossom blight	Zineb
	Downy mildew	Mancozeb Maneb Zineb
	Gummy stem blight	Mancozeb Maneb Zineb
	Leaf spots	Mancozeb Maneb
	Scab	Mancozeb Zineb

Table 4. EBDC Fungicide Registered for Control of Diseases of Fruits*

Fruit	Disease	Registered EBDC
Apples	Bitter rot	Mancozeb Polyram Zineb
	Black rot	Maneb Polyram Zineb
	Blotch	Zineb
	White rot	Polyram Zineb
	Brooks spot	Zineb
	Brown rot	Mancozeb Polyram
	Bullseye rot	Maneb
	Cedar apple rust	Mancozeb Maneb Polyram Zineb
	Fire blight	Zineb
	Flyspeck	Mancozeb Maneb Polyram Zineb
	Frogeye leaf spot	Zineb
	Quince rust	Zineb
	Rust	Mancozeb
	Scab	Amobam Mancozeb Maneb Polyram Zineb
	Sooty blotch	Mancozeb Maneb Polyram Zineb

*Based on EPA microfishe label and registration files.

Fruit	Disease	Registered EBDC
Apricots	Brown rot	Maneb
	Green rot (Jacket rot)	Maneb
	Leaf curl	Zineb
	Shot hole	Maneb Zineb
Blackberry	Anthracnose	Zineb
	Leaf rust	Zineb
	Rust	Zineb
	Septoria leaf spot	Zineb
Blueberry	Botrytis blight	Mancozeb
Boysenberry	Anthracnose	Zineb
	Rust	Zineb
	Septoria leaf spot	Zineb
Cherry (ALL)	Leaf spot	Zineb
	Shot hole	Zineb
Citrus (ALL)	Greasy spot	Zineb
Cranberries	Fruit rots	Mancozeb Zineb
	Lophodermium	Maneb
Currant	Leaf spots	Zineb
Dewberry	Cane rust	Zineb
Gooseberry	Leaf spots	Zineb

Fruit	Disease	Registered EBDC
Grapes	Bitter rot	Zineb
	Black rot	Mancozeb Maneb Zineb
	Brown rot	Zineb
	Bunch rot (Botrytis)	Mancozeb Zineb
	Dead-arm	Mancozeb Zineb
	Downy mildew	Mancozeb Zineb
	Ripe rot	Zineb
Kumquat	Greasy spot	Zineb
Lemons	Storage rots	Zineb
Loganberry	Anthracnose	Zineb
	Septoria leaf spot	Zineb
Nectarine	Brown rot	Maneb Zineb
	Coryneum blight (leaf blight, shot hole)	Maneb Zineb
	Leaf curl	Zineb
	Leaf spot	Zineb
	Scab	Zineb
Papaya	Anthracnose	Mancozeb Maneb
	Black spot	Maneb
	Phytophthora fruit rot	Mancozeb

Fruit	Disease	Registered EBDC
Peach	Brown rot	Maneb Zineb
	Leaf curl	Zineb
	Leaf spts	Zineb
	Scab	Zineb Maneb
	Shot hole (blight)	Maneb Zineb
Pear	Bitter rot	Mancozeb
	Black rot	Mancozeb
	Fire blight	Zineb
	Flyspeck	Mancozeb
	Rust	Mancozeb
	Scab	Mancozeb
	Sooty blotch	Mancozeb Zineb
	Pear psylla insect	Mancozeb
Pineapple	Heart rot	Mancozeb
Plum and prunes	Black knot	Zineb
	Brown rot	Zineb
	Leaf curl	Zineb
	Leaf spots	Zineb
	Scab	Zineb
Raspberry	Anthracnose	Zineb
	Septoria leaf spot	Zineb
Strawberry	Stem rot	Zineb

Table 5. EBDC fungicides registered for use in turfgrass disese control.*

Fungicide	Diseases Listed on Labels
Maneb	Melting out Brown patch Stem rust Leaf rust Stripe smut Dollar spot
Zineb	Helminthosporium Rust Slime mold Cottony blight Fading out Leaf spot Melting out Pythium Slime mold Curvularia
Mancozeb	Algae Fusarium root rot Fusarium Helminthosporium Pythium Rhizoctonia Rust Sclerotinia Slime molds Brown patch Copperspot Dollar spot Fusarium blight Melting out Pink snow mold Pythium blight

*Based on EPA microfische label and registration files.

Table 6. Diseases of Flower Crops in Which EBDC Fungicides Have Been Received for Control*

	Maneb	Registered
Aster	Rust	Yes
Chrysanthemum	Ascochyta Blight	Yes
	Botrytis Petal Spot	Yes
Geranium	Rust	No
Rose	Black Spot	Yes
Snapdragon	Rust	Yes

	Zineb	Registered
Aster	Rust	Yes
Carnation	Alternaria Leaf Spot and Branch Rot	Yes
	Rust	No
	Greasy Blotch	No
Chrysanthemum	Ascochyta Blight	Yes
	Rust	Yes
	Botrytis Petal Spot	Yes
Celosia	Leaf Spots	No
Columbine	Rust	No
Dahlia	Botrytis Blight	Yes
Delphinium	Leaf Spot	Yes
Freesia	Botrytis Leaf Blight	No
Geranium	Botrytis Blight	Yes
	Rust	No
Gladiolus	Botrytis Leaf Blight	Yes
Hollyhock	Rust	Yes
Hydrangea	Leaf Spot	Yes
Impatiens	Leaf Spot	No
Lily	Botrytis Blight	Yes
Marigold	Leaf Spot	No
Nasturtium	Leaf Spot	No
Pansy	Anthracnose	Yes
	Leaf Spot	Yes
	Scab	No
Peony	Botrytis Blight	Yes
	Leaf Spots	No
Phlox	Leaf Spot	No
Rose	Black Spot	Yes
Snapdragon	Rust	Yes
	Anthracnose	Yes
	Downy Mildew	Yes
Stock	Leaf Spot	No
Sweet Pea	Anthracnose	No
	Leaf Spot	No

*Based on State experiment station bulletins.

Table 7. Common Woody Ornamentals Diseases in Which EBDC Fungicides Have Been Recommended for Control*

	Mancozeb	Registered
European horse chestnut	Leaf blotch	No
	Leaf spot	Yes
Camellia	Flower blight	Yes
Hornbeam	Leaf spots	No
Hickory	Leaf spot	Yes
Catalpa	Leaf spot	No
Hackberry	Leaf spot	No
Redbud	Leaf spot	No
Fringetree	Leaf spot	No
Virgin's bower	Leaf spot and stem rot	No
Dogwood	Leaf spots	Yes
Cotoneaster	Leaf spots	No
Hawthorn	Leaf blight	No
	Rusts	No
	Scab	No
Bush honeysuckle	Leaf spot	No
Eleagnus	Leaf spot	No
Euonymus	Anthracnose	No
Beech	Leaf spot	No
Forsythia	Leaf spot	No
Franklinia	Leaf spot	No
Coffee tree	Leaf spot	No
Witch hazel	Leaf spot	No
Winterberry	Tar spots	No
	Leaf spots	No
Larch	Needle rusts	No
Privet	Leaf spot	No
Honeysuckle	Leaf blight	Yes
Magnolia	Leaf spot	No
Magnolia	Leaf spot	No
Flowering crabapple	Rust	Yes
	Scab	Yes
	Bitter rot	Yes
	Sooty blotch	Yes
Pachysandra terminalis	Twig blight	Yes
Boston ivy	Leaf spot	No
Princess tree	Leaf spot	No
Mock orange	Leaf spot	No
Cherry laurel	Leaf spot	No
Ornamental peach	Leaf curl	Yes
Flowering Japanese cherries	Witch's broom	No
Oak	Leaf blister	No
	Leaf spot	No

*Based on State experiment station bulletins.

Table 7 (cont'd.)

	Mancozeb (cont'd.)	Registered
Azalea	Azalea petal blight	Yes
	Azalea leaf spot	Yes
	Dieback	No
	Leaf spots	No
Rose	Rhododendron petal blight	Yes
	Black spot	Yes
	Leaf spot	Yes
	Brown canker	No
	Brand canker	No
	Common stem canker	No
	Crown canker	No
	Cane blight canker	1No
	Alternaria leaf spot	No
	Downy mildew	Yes
Mountain ash	Leaf rusts	No
	Scab	No
Lilac	Phytophthora blight	No
Viburnum	Downy mildew	No

	Maneb	Registered
Maples	Leaf blister	No
Camellia	Flower blight	Yes
Dogwood	Leaf spots	Yes
Nazelnuts	Leaf curl	No
Pinus	Needle cast	Yes
	Brown spot	Yes
White pine	Fusiform rust	Yes
Rose	Black spot	Yes
	Leaf spot	Yes
	Rust	Yes
	Cercospora leaf blight	Yes

	Zineb	Registered
Maples	Purple eye leaf spot	No
European horse chestnut	Leaf spot	Yes
<u>Amelanchier</u> serviceberry	Rust	No
Boxwood	Rusts	No
Hickory	Leaf spot	Yes
Flowering quince	Rust	Yes
	Leaf spots	Yes
Dogwood	Flower and leaf blight	Yes
	Leaf spots	Yes
Hawthorn	Leaf blight	No
	Rusts	No
	Leaf spot	Yes
Euonymus	Leaf spot	Yes
Ash	Leaf spot	No

Table 7 (cont'd.)

	Zineb	Registered
English ivy	Stem spot	Yes
	Twig blight	Yes
Butternut	Brown leaf spot	No
Japanese walnut	Yellow leaf blotch	No
Mountain laurel	Leaf spot	No
	Blight	No
Flowering crabapple	Rust	Yes
	Frogeye leaf spot	Yes
White pine	Southern cane rust	No
Oak	Anthracnose	Yes
Azalea	Azalea petal blight	Yes
	Azalea gall	Yes
	Leaf scorch	Yes
	Rust	No
	Azalea leaf spot	Yes
Flowering currant and gooseberries	Leaf spots	Yes
Rose	Botrytis blightht	Yes
	Leaf spot	Yes
	Rust	Yes
	Downy mildew	Yes
Willow	Gray scab	No
	Leaf spot	No
Lilac	Leaf spot	Yes
Hemlock	Blister rust	No
	Needle rust	No
Periwinkle	Blight	No
Pinus	Leaf casts	No

Table 8. Estimated world uses of EBDC fungicides ih 1975*

Crops	Millions of Pounds
Plantation	4.410
Bananas	8.875
Fruits and Nuts	27.344
Rice	3.518
Major Field Crops	10.713
Vegetables	35.692
Potatoes	60.463
Tomatoes	19.267
Seed Treatment	3.509
Turf and Ornamentals	0.533
Vineyards	79.996
Total All Uses	255.320

*Based on assessment team compilations and sales estimates by Rohm and Haas Chemical Company.

An analysis of hazards to aquatic organisms resulting from EBDC usage on cranberries

According to information the assessment team has recieved from the main cranberry production areas, EBDC's are not applied to water during cranberry production. In Wisconsin and Oregon, the crops are grown and harvested as dry land agriculture. In Massachusetts and New Jersey fungicides are applied to cranberries only during bloom periods to control fruit rots. The bogs are drained before bloom and are not re-flooded until approximately 42 days after fungicide application in New Jersey and 64 days in Massachusetts. All fungicide application is on unflooded land.

AN ANALYSIS OF LEVELS OF EXPOSURE TO DIETARY RESIDUES OF ETHYLENEBISDITHIOCARBAMATE AND ETHYLENETHIOUREA RESIDUES

The purpose of this section is to provide reasonably accurate estimates of human exposure to residues of the EBDC's and ETU by way of dietary intake. No attempt is made to assess the toxicological significance of the risk exposure levels derived since this aspect is not within the realm of the expertise of the team.

Maximum contributions of EBDC/ETU residues to the human diet can be estimated in various ways, none of which gives a highly accurate assessment of the actual situation. Nevertheless, some estimates appear to be more realistic than others due to the accuracy of the assumptions on which their calculation is based. The dietary exposure levels presented herein have been made under a variety of assumptions, some of which are routinely applied by regulatory agencies. In each instance, the calculations provided are based on the average food intake (1.5 kg/day) and relative proportions of food ingested in the total diet [Lehman (1962)] of an average 60 kg adult which are all factors presently used by the Toxicology Branch of the EPA in setting tolerances.

A. Exposure estimates based on food consumption and tolerances.

Potential consumption of EBDC residues may be calculated from consumption data for food items on which tolerances have been

established. In this type of calculation, two basic assumptions are routinely applied: (1) All of a raw agricultural commodity for which an EBDC tolerance (mancozeb, maneb, zineb, or metiram) has been granted, is, in fact, treated. (2) At the time of consumption, the EBDC residue on each food item is equivalent to the maximum EBDC tolerance established for that commodity. Neither of these assumptions is valid in the light of current agricultural production and consumer practices. Nevertheless, the present EBDC-RPAR issued by the EPA is based, in part, upon estimates derived in this manner.

In the report by Beach and Weaner (1977), cited in the EPA-EBDC-RPAR Position Document I, a theoretical daily intake [TDI] of EBDC residues of 0.0608 mg/kg body weight is calculated. This value has been recalculated as shown in Table 1, with the inclusion of two commodities not considered in the original EPA calculation (saurkraut and fennel). The derived value of 0.0516 mg/kg body weight is lower than the level shown in the earlier report because in that calculation certain food factor data were entered repeatedly. According to Lehman's (1962) data on food consumption "pumpkins and squash" constitute 0.19% of the total diet, yet Beach and Weaner enter pumpkin, squash, winter squash, and summer squash into their calculations at 0.19% each for a total of 0.76% of the diet. Similar redundancies are evident in the earlier report for lettuce, edible offals, nuts, kale, and berries, as shown in Table 2. This error results in an overstatment by the EPA of 0.009 mg/kg body weight which by itself is greater than the ADI.

B. Application of EBDC USE Data to Risk Exposure Calculations

The assumption that all of a given raw agricultural commodity is treated with any or all of the EBDC's registered for use on that crop was cited earlier as being invalid. While it is not unlikely that 100% of a particular crop might be treated within one or two production areas, instances in which the entire U.S. production of that crop is treated would indeed be rare. Whether an EBDC is used on a crop in a particular production area depends upon a number of highly variable factors including the susceptibility to disease of the varieties grown, the incidence of disease, climatic conditions, and grower preference for alternative materials where these are available.

In the interests of safety, it might be argued that consumers in those production areas where all of the acreage of a particular crop is treated with EBDC's are exposed to higher residue levels than consumers purchasing the same food item in production areas where none of the acreage is treated. On the contrary, the sophistication of the present food distribution and marketing systems in the United States is such that produce from several different regions may be available at any one location. For example, one third of New York's apple crop (12% of total U.S. production) is treated with EBDC's, yet consumers in New York can purchase apples from Washington State (36% of total U.S. production) at almost any time during the year and none of these need to be treated with EBDC's. Similarly, a store in Missouri may offer potatoes from

Idaho (24% U.S. production, 50% EBDC treated), Maine (8% U.S. production, 90% EBDC treated) and New York (4% U.S. production, 70% EBDC treated) for sale at the same time. In this last scenario, the Missouri consumer has a 22% chance $[100[(0.24 \times 0.50)_{ID} + (.08 \times 0.90)_{ME} + (0.04 \times 0.70)_{NY}]\ )]$ of purchasing potatoes from that store which were grown on acreage treated sometime during the season with one or more EBDC's.

Thus, the probability of EBDC treatment needs to be considered in any assessment of exposure. Table 3 presents data obtained in our survey of EBDC usage on 26 major crops. The states surveyed with respect to the use of EBDC's on a given crop in each case represented a combined minimum of 70% (average 85% $\pm$ 10%) of the total U.S. production of that crop (1976 crop production statistics, USDA/SRS/CRB data). If it is assumed, on the basis of EBDC registered uses, that the food items which might be treated with any of the EBDC's constitute a total of 43% (Table 1) of the dietary intake, then the 26 items in this survey (39.29% of the total diet) represent over 90% of that portion of the diet which might be treated. The percent of the food in the total diet which is treated with EBDC can be estimated from the sum of the products obtained by multiplying the food factor times the percent of U.S. production treated (Table 4). This value is estimated to be for all items for which the EBDC's are registered. Use factors, therefore, can be entered into risk assessment calculation as a means of accounting for that fraction of total consumption which has not been treated.

of U.S. production ...

... was treated ... the ...

... for only ... in ...

... consumer ...

... (0.06 x 0. ...) ... of production.

... which were grown ...

... with other crops.

Thus, the probability of ...

assessment of exposure ...

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... uses, that the food items which ...

... EXDC s considered a total of ... (Table 1) ...

..., then the 24 items in this survey ...

... over 80% of that portion of the ...

The percent of the food ...

... can be estimated from the ...

... the food factor times the ...

... This value is estimated ...

... are determined. ...

... as ...

... consumption which ...

It should be emphasized that these data represent only that portion of the total U.S. production of 26 crops which is treated at some time with an EBDC fungicide during any given season. No judgment can be based on this data as to the significance of EBDC's in the production of a given crop in a particular region. These estimates may differ from use estimates based upon the amount of chemical applied due to variations in yield. For example, young non-bearing fruit orchards may be treated with EBDC's yet do not contribute to overall fruit production. In addition, some treated acreage is not harvested due to economic or environmental factors.

Table 5 shows the calculation of the theoretical daily intake of EBDC residues based on the presence of maximum tolerance residues and the use pattern data derived in Table 3 for 26 major crops. If is is assumed that the general use patterns demonstrated for the crops surveyed are representative of the EBDC usage on the commodities representing 3.71% of the total diet which were not surveyed but for which EBDC's are registered for use, then a maximum TDI of 0.0132 mg EBDC per kg of body weight could be expected.

Since all of the estimates obtained in the use pattern survey were those of extension personnel and plant pathologists familiar with current production practices in their respective states, they are probably the most accurate figures available. Nevertheless, if, in the interests of safety, we make a further assumption that each of the estimates provided was understated by 10%, then the TDI of EBDC residues (based on maximum tolerances) could be as high as 0.0145

[illegible]

Total U.S. production [illegible]

with an EBDC fungicide during [illegible]

is based [illegible] this data [illegible]

duction of [illegible] particular [illegible] Thus

[illegible] may differ from [illegible] based upon [illegible]

due to variations in [illegible]

[illegible] may be treated [illegible]

fruit production. In addition, [illegible]

due to economic [illegible]

Table 5 shows the calculation of [illegible]

residues based on the [illegible]

pattern data derived [illegible] Table [illegible]

that the general use pattern [illegible]

are representative of the [illegible]

[illegible] of the total [illegible] which [illegible]

registered for use. [illegible]

[illegible] body weights would be expected.

[illegible] all of the estimates [illegible]

of extension personnel [illegible]

[illegible] production practices in [illegible]

[illegible] only the [illegible]

[illegible]

mg/kg body weight or only 28% of that amount (.0516 mg/kg) estimated on the earlier assumption that 100% of each crop was treated. Even this estimate, however, is overstated because it is based on the use of maximum tolerance residues established arbitrarily for enforcement purposes and not as actual, or even as representative residue levels.

C. Use of Measured Residues for Risk Exposure Estimations

Since tolerance residues are established primarily for legal purposes so that heavily contaminated produce can be legally withheld from the marketplace, their use in caluclating actual risk exposure hazards is of little practical value. In actual practice, when EBDC fungicides are used in accordance with the label restrictions, the harvest of "farm gate" residues encountered are much less than the legal tolerance limits. This point is illustrated in Table 6 based on maneb residue data submitted by the duPont Company in petitions for various tolerances. The residue levels shown for maneb represent, in each case, the maximum residue obtained when the material was applied according to the restrictions noted when the tolerance was subsequently granted.

Calculation of a TDI based on harvest residues was not possible at this writing because of the limited data available. Such a calculation, however, would probably be moot since "farm gate" residues, although less than tolerance limits, are still greater than those which the consumer might normally be expected to encounter. This is

due to the fact that most fresh and commercially processed fruits and vegetables routinely undergo some treatment which physically reduces surface pesticide residues.

Post-harvest procedures which are most routinely employed include: trimming (e.g., removal of outer wrapper leaves of cabbage, celery tops, carrot tops, and the peeling of various fruits for processing), brushing (e.g., normal grading procedures to remove surface pubescence on peaches and residues on apples and pears), washing (e.g., various post-harvest dips and rinses to remove pesticide and soil residues on a variety of fruits and vegetables). Many of these post-harvest treatments are made prior to first shipping to the wholesale market. Additional trimming and washing of fresh produce also occurs in the retail market before the produce is displayed for the consumer. Finally, many fresh food items undergo further trimming, peeling, and washing procedures in their preparation by the consumer before ingestion.

The studies by Phillips (1977) indicate that washing raw agricultural produce removed from 33 to 87% of the EBDC residue and the majority of the ETU residue prior to processing. Von Stryk (1976), working with greenhouse tomatoes treated with recommended rates of mancozeb, noted that harvest residues of 3.2-4.7 ppm were reduced to as little as 0.4-0.8 by mechanical brushing. Thus, the routine physical removal of EBDC and ETU residues prior to processing needs to be considered as a very real factor in reducing the dietary risk exposure to these compounds.

EBDC residues can also be markedly reduced by cooking which is normally employed for many processed food items or for food items purchased fresh but cooked before consumption. Unlike the physical treatments noted above, however, the reduction of EBDC residues through cooking does not necessarily reduce the toxic hazard they may present since a proportion of the EBDC is converted to ETU. Newsome (1976), for example, demonstrated a 38 - 48% (molar basis) conversion of EBDC's to ETU during the heating of homogenates of field treated tomatoes. Tomatoes fortified with 2 ppm of mancozeb and then fried resulted in a 45% (molar basis) conversion to ETU (Von Stryk, 1976). Because of these findings and similar results from other studies, the effects of cooking on EBDC/ETU residue exposure must also be accounted for in any assessment of the risks these levels may present.

The most realistic exposure levels on which to base consumer risk assessments would be those derived from data on residues detected in a total diet program including a variety of fresh and processed food items. Because of the limitations of the CS_2-evolution analytical procedure for dithiocarbamates (non-specific, low recoveries, and inability to detect ETU) used in the Food and Drug Administration's (FDA) "Total Diet Program," residue data acquired in that program from 1964 to 1970 are suspect and, therefore, cannot be considered in this analysis. Newer methods employing gas liquid chromatography (GLC) methods capable of distinguishing the EBDC's from other dithiocarbamates and from ETU (Newsome, 1972; and, notably, Uno, et al., 1977) have only recently been developed and

proven. As a consequence, only limited data have been published on EBDC/ETU residues on food items.

Pecks, et al. (1977) described ETU levels in the Canadian food supply in 1972. Only one third of the 167 samples collected (fresh and processed) contained detectable levels of ETU (0.01 ppm). Most of these ETU levels (92%) were at the level of 0.02 ppm or less. The highest levels were found in 3 of 5 samples of canned spinach (ave. 0.047 ppm., range 0.040 - 0.050 ppm) and 3 of 5 samples of fresh orange peel (ave. 0.083 ppm, range 0.030 - 0.150 ppm). Recovery levels were 96% ± 8.9%). Although Newsome's (1972) GLC method was used, positive "peaks" were not confirmed by mass spectrometry. The data are, therefore, also suspect in the light of the more recent results of Uno, et al. (1977) who employed confirmatory precedures which eliminate the detection of "false positives."

Using an improved version of Newsome's (1976) method, coupled with mass spectrometry to confirm the residues detected, Uno et al. (1977) examined EBDC and ETU levels in 59 samples of 16 agricultural commodities. EBDC residues were found on one sample each of strawberry (1.21 ppm), spinach (1.00 ppm) and cucumber (0.34 ppm). ETU residues of 0.076 ppm and 0.075 ppm respectively were found on the strawberry and cucumber samples above. An additional strawberry sample was shown to contain 0.008 ppm ETU.

On the basis of these data, if we make the broad assumption that the average EBDC and ETU residues on <u>all</u> agricultural produce for which the EBDC's are registered for use [43% of the total diet, Table 1] are 0.043 mg/kg of body weight and 0.003 mg/kg of body weight respectively, then the maximum dietary risk exposure to these materials can be shown to be equivalent or less than the current FAO/WHO ADI value of 0.005 mg/kg of body weight.

EBDC:

$$\frac{43\%\text{ (food factor)} \times 0.043\text{ mg/kg} \times 1.5\text{ kg (consumption)}}{60\text{ kg}} = \begin{array}{l}0.00046\\ \text{mg.kg}\\ \text{body weight}\end{array}$$

ETU:

$$\frac{43\%\text{ (food factor)} \times 0.003\text{ mg/kg} \times 1.5\text{ kg (consumption)}}{60\text{ kg}} = \begin{array}{l}0.00003\\ \text{mg/kg}\\ \text{body weight}\end{array}$$

Considering that only 12% of the food in the total diet is actually treated with EBDC's during production (Table 4), yet another margin of safety exists and the exposure level needs to be recalculated as shown below:

EBDC:

$$\frac{12\% \times 0.043\text{ mg/kg} \times 1.5\text{ kg}}{60\text{ kg}} = \begin{array}{l}0.00129\\ \text{mg/kg}\\ \text{body weight}\end{array}$$

ETU:

$$\frac{12\% \times 0.003\text{ mg/kg} \times 1.5\text{ kg}}{60\text{ kg}} = \begin{array}{l}0.000009\\ \text{mg/kg}\\ \text{body weight}\end{array}$$

Assuming the stoichiometric conversion of <u>all</u> the ingested EBDC residues (as maneb, conversion factor of 0.2852), the total ETU

exposure level (including that present as residue at ingestion) would be only 0.000059 mg/kg. Using the no effect level of 5 mg/kg (EPA-EBDC-RPAR Position Documenmt 1) for ETU in rats, an exposure of 0.000059 mg/kg results in a safety factor of 84,746, well above the 250 value calculated by Beach and Weaner (1977). Based on the information and calculations presented here, the amounts of EBDC and ETU residues in the total diet as well as the potential exposure to ETU as the result of its conversion from EBDC, the assessment team concludes that exposure through ingestion is minimal.

In summary, it is both necessary and appropriate to note the following. The problem with exposure estimates based on the broad assumptions routinely used by the EPA is that so many "margins of safety" are entered, and then multiplied, that the final calculation is greatly inflated and has little relationship to the actual risk involved. It would appear more realistic to first calculate the probable exposure levels using experimental data where this is available and, where it is not, then to apply assumptions which are consistent with current agricultural practices. A value derived in this manner can then be considered as a descriptive value and, hence, is useful in interpreting the exposure risk. If it is necessary to compute a margin of safety, this should be done only on the completed calculation.

SUMMARY AND CONCLUSIONS

1. We find the respective EBDC and ETU exposure levels of 0.0608 and 0.02 mg/kg body weight cited in the EPA EBDC RPAR are unnecessarily high and exceed our estimates by two orders of magnitude.

2. EPA's calculations of EBDC exposure levels are based on the assumptions that all of a raw agricultural commodity for which an EBDC is registered is treated and that, at the time of consumption, each treated food item carries residues equivalent to the maximum EBDC tolerance granted for that crop. We feel these assumptions are unrealistic in that they do not reflect current agricultural and consumer practices.

3. The use of harvest residue data for exposure calculations is also unrealistic in the light of post-harvest treatments which markedly reduce (33-87%) EBDC residues on the surfaces of food crops.

4. The most realistic exposure calculations must be based on a total diet program such as the FDA conducted for dithiocarbarmates prior to 1970. The data obtained in that program, however, are suspect because of the limitations of the analytical methods employed which were cited in the RPAR statement. More sophisticated and reliable analytical methods, utilizing

gas-liquid chromatography and mass spectrometry, have only recently been employed and, as a result, only limited EBDC and ETU data are available at this time.

5. We estimate EBDC and ETU residue exposure levels are 0.000129 and 0.00009 mg/kg of body weight, respectively. This level of EBDC exposure is well below the FAO/WHO recommended temporary ADI of 0.005 mg/kg of body weight. The total ETU (residue and EBDC conversion) exposure level is 0.000059 mg/kg of body weight which allows a safety factor of 84,746 based on a no-effect level of 5 mg/kg rat body weight.

Table 1 . Calculation of the theoretical daily intake of EBDC residues based on consumption data for food items on which tolerances have been established.

Food items	Food factors(%)[1]	Tolerances (mg/kg)[2] mancozeb	maneb	zineb	metiram	EBDC Contribution to daily intake (mg/kg)[3]
Wheat flour	8.05	1 FA	-	-	-	0.0805
Potatoes	7.00	1 IT	0.1	0.5	0.5	0.0700
Citrus	4.00	-	-	7	-	0.2800
Tomatoes	3.34	4	4	4	4	0.1336
Melons	1.98	4	4	4	4	0.0792
Apples	1.81	7	7	2	2	0.1267
Bananas (pulp only)	1.51	0.5	0.5	-	-	0.0076
Sweet corn	1.19	0.5	5	5	0.5 IT	0.0595
Lettuce & escarole[4]	1.15	-	10	10	-	0.2875
- Romaine		-	-	25	-	
Peaches	1.03	-	10	7	-	0.1030
Onions	1.01	0.5	7	7	-	0.0707
Celery	.76	5	5	5	5	0.0308
Snap beans	.74	-	7	7	-	0.0518
Cucumber	.73	4	4	4	4	0.0292
Edible offals[4]	.69					0.0035
- Kidney		0.5	-	-	-	
- Liver		0.5	-	-	-	
Nuts[4]	.60					0.0420
- Almonds		-	0.1	-	-	
- Peanuts		0.5	-	7	0.5 IT	
- Pecans		-	-	-	0.5	
Carrots	.55	2	7	7	-	0.0385
Dry beans	.50	-	7	7	-	0.0350
Cabbage	.49	-	10	10	-	0.0490
Green peas	.49	-	-	7	-	0.0343
Beets	.44	-	-	7	-	0.0308
Cauliflower	.43	-	10	7	-	0.0430
Saurkraut (as cabbage)	.42	-	10	10	-	0.0420
Pears	.32	10	-	7	-	0.0320
Grapes	.32	7	7	7	-	0.0224
Egg plant	.32	-	7	7	-	0.0224
Spinach	.29	-	10	10	-	0.0290
Peppers	.25	-	7	7	-	0.0175
Asparagus	.23	0.1	-	-	-	0.0002
Plum & prunes	.23	-	-	7	-	0.0161
Pumpkin & squash[4]	.19					0.0133
- Pumpkin		-	7	7	-	
- Squash		-	-	4	-	
- Summer squash		4	4	7	-	
- Winter squash		-	4	-	-	
Broccoli	.19	-	10	7	-	0.0190
Strawberries	.19	-	-	7	-	0.0133
Cherries	.17	-	-	7	-	0.0119
Brussel sprouts	.16	-	10	7	-	0.0160
Kale[4]	.14	-	10	10	-	0.0350
- Swiss chard		-	-	25	-	
- Collards		-	-	25	-	
- Mustard greens		-	10	10	-	

[continued]

Table 1 . Continued - 2

Food items	Food factors(%)[1]	Tolerances (mg/kg)[2]				EBDC contribution to daily intake (mg/kg)[3]
		mancozeb	maneb	zineb	metiram	
Dry peas	.12	-	-	7	-	0.0084
Apricots	.12	-	10	7	-	0.0120
Raisins & currants	.12	28 FA	-	7	-	0.0336
Cranberries	.10	7	7	7	-	0.0070
Rye flour	.08	1 FA	-	-	-	0.0008
Berries, other[4]	.06					0.0042
- Boysenberries		-	-	7	-	
- Dewberries		-	-	7	-	
- Gooseberries		-	-	7	-	
- Loganberries		-	-	7	-	
- Youngberries		-	-	7	-	
Spices[4]	.06					0.0060
- Fennel		10	-	-	-	
- Parsley		-	-	7	-	
Nectarines	.06	-	10	7	-	0.0060
Figs	.05	-	7	-	-	0.0035
Raspberries	.04	-	-	7	-	0.0028
Blackberries	.03	-	-	7	-	0.0021
Rhubarb	.001	-	10	-	-	0.0001
Total	42.751					2.0628

FA = food additive IT = interim tolerance - = not applicable

1 Quarterly Bulletin of the Association of Food & Drug Officials 26(3): 149-151 (July, 1962), currently used by the EPA.

2 21 CFR 123.460, 40 CFR 180.110, 40 CFR 180.115, 40 CFR 180.176, and 40 CFR 180.217.

3 Calculated on the basis of the maximum tolerance established for any EBDC fungicide registered for use on a particular commodity

4 Food item and food factor published in the Quarterly Bulletin (see footnote 1) under which are grouped similar food items not specifically listed in that publication but for which tolerances have been granted. This is done in order to avoid redundancies evident in EPA calculations where, for example, lettuce, endive (escarole), and romaine are each listed as constituting 1.15% of the total diet.

<u>Quantity in diet:</u> 1.5 kg* x 2.0628 mg/kg = 3.0942 mg

<u>Theoretical daily intake:</u> 3.0942 mg/60 kg human* = 0.0516 mg/kg of body weight

* Calculations are based on the average values for the amount of food eaten per day (1.5 kg) by a 60 kg human adult, as currently used by the Toxicology Branch, EPA, in setting tolerances.

TABLE 2. Comparison of EBDC exposure levels on various food items as calculated in accordance with Lehman's (1962) food factor data as published and as shown by Beach & Weaner (1977) for the EPA. EBDC residues are represented by the maximum tolerance allowed for each crop.

EPA's application of Lehman's data				Strict use of Lehman's data			
Food item	Food factor (%)	Maximum tolerance (mg/kg)	Contrib. to daily intake (mg/kg)	Food item	Food factor (%)	Maximum tolerance (mg/kg)	Contrib. to. daily intake (mg/kg)
Lettuce	1.15	10	0.1150	Lettuce & escarole	1.15	25	0.2875
Endive	1.15	10	0.1150				
Romaine	1.15	25	0.2875				
Kidney	0.69	0.5	0.0035	Edible offals	0.69	0.5	0.0035
Liver	0.69	0.5	0.0035				
Peanuts	0.60	7	0.0420	Nuts	0.60	7	0.0420
Almonds	0.60	0.1	0.0006				
Pecans	0.60	0.5	0.0030				
Pumpkin	0.19	7	0.0133	Pumpkin & squash	0.19	7	0.0133
Squash	0.19	4	0.0076				
Summer squash	0.19	7	0.0133				
Winter squash	0.19	4	0.0076				
Kale	0.14	10	0.0140	Kale	0.14	25	0.0350
Mustard grns.	0.14	10	0.0140				
Collards	0.14	25	0.0350				
Swiss chard	0.14	25	0.0350				
Boysenberries	0.06	7	0.0042	Berries, other (excludes rasp-, black-, cran-, & strawberries)	0.06	7	0.0042
Dewberries	0.06	7	0.0042				
Gooseberries	0.06	7	0.0042				
Loganberries	0.06	7	0.0042				
Youngberries	0.06	7	0.0042				
TOTAL	8.25%		0.7309	TOTAL	2.83		0.3855

Error calculation: 0.7309 mg/kg - 0 3855 mg/kg = 0.3454 mg.kg
Quantity in diet (error value only): 0.3454 mg/kg x 1.5 kg (daily intake) = 0.5181 mg
Theoretical daily intake (error value only): 0.5181 mg / 60 kg adult = 0.0086 mg/kg b-w

TABLE 3. Ethylenebisdithiocarbamate (EBDC) fungicide use patterns in the United States on 26 major food crops.

Commodity / Site	% in diet[1] of item	% U.S. production[2]	% site treated[3]	% U.S. production treated[4]
WHEAT	8.05			
Kansas		15.8	14.0	2.2
N. Dakota		13.4	25.0	3.4
Montana		7.8	10.0	0.8
Oklahoma		7.0	5.0	0.4
Washington		6.7	0.0	0.0
Minnesota		6.1	40.0	2.4
Texas		4.8	0.0	0.0
Nebraska		4.4	10.0	0.4
Illinois		3.4	5.0	0.2
Idaho		3.2	2.0	0.1
Ohio		3.1	5.0	0.3
Other		24.3	12.6*	3.1
Total U.S. wheat treated				13.2
POTATOES	7.00			
Idaho		24.1	50.0	12.1
Washington		15.8	20.0	3.2
Oregon		8.2	48.0	3.9
Maine		7.8	90.0	7.0
California		6.8	60.0	4.1
Wisconsin		4.3	75.0	3.2
Minnesota		3.7	24.0	0.9
New York		3.7	70.0	2.6
Other		25.6	54.6*	14.0
Total U.S. potatoes treated				51.0
CITRUS	4.00			
Florida		73.1	25.0	18.3
California		18.7	2.0	0.4
Texas		5.2	0.0	0.0
Arizona		3.0	0.0	0.0
Other		0.0		
Total U.S. citrus treated				18.7
TOMATOES	3.34			
California		71.4	11.0	7.9
Ohio		6.9	100.0	6.9
Florida		6.0	90.0	5.4
Indiana		3.1	84.0	2.6
New Jersey		2.7	56.0	1.5
Other		9.9	68.2	6.8
Total U.S. tomatoes treated				31.1
MELONS	1.98			
California		27.1	2.0	0.5
Florida		25.7	89.0	22.9
Texas		16.1	60.0	9.7
Georgia		6.9	66.0	4.6
Arizona		4.6	1.0	0.05
Other		19.6	43.6*	8.5
Total U.S. melons treated				46.3

TABLE 3 Continued - 2

Commodity / Site	% in diet[1] of item	% U.S. production[2]	% site treated[3]	% U.S. production treated[4]
APPLES	1.81			
Washington		35.6	0.0	0.0
New York		12.0	33.0	4.0
Michigan		8.0	75.0	6.0
Pennsylvania		5.8	90.0	5.2
N. Carolina		4.3	90.0	3.9
Virginia		2.8	90.0	2.5
Illinois		1.4	75.0	1.1
Other		30.1	64.7*	19.5
Total U.S. apples treated				42.4
BANANAS	1.51			
Hawaii		100.0	1.0	1.0
Total U.S. bananas treated				1.0
SWEET CORN	1.19			
Wisconsin		18.8	1.0	0.2
Minnesota		17.4	28.0	4.9
Oregon		10.8	0.0	0.0
Florida		10.2	97.0	9.9
Illinois		8.4	33.0	2.8
Washington		7.2	0.0	0.0
Other		27.2	26.5*	7.2
Total U.S. sweet corn treated				25.0
LETTUCE & ESCAROLE	1.15			
California		70.8	3.0	2.1
Arizona		13.6	50.0	6.8
Florida		4.2	100.0	4.2
Colorado		2.2	90.0	2.0
New Mexico		1.8	50.0	0.9
Other		7.4	58.6*	4.3
Total U.S. lettuce & escarole treated				20.3
PEACHES	1.03			
California		65.0	0.0	0.0
S. Carolina		8.5	5.0	0.4
Georgia		6.6	0.0	0.0
Pennsylvania		3.6	0.0	0.0
New Jersey		2.7	0.0	0.0
Other		13.6	1.0*	1.4
Total U.S. peaches treated				1.8
ONIONS	1.01			
California		25.2	45.0	11.3
Texas		19.0	75.0	14.3
Oregon		12.6	100.0	12.6
New York		10.3	65.0	6.7
Idaho		8.3	100.0	8.3
Colorado		6.2	50.0	3.1
Wisconsin		1.2	50.0	0.6
Other		17.2	69.3	11.9
Total U.S. onions treated				68.8

TABLE 3 Continued - 3

Commodity / Site	% in diet[1] of item	% U.S. production[2]	% site treated[3]	% U.S. production treated[4]
CABBAGE (incl. saurkraut)	.91			
Florida		17.3	92.0	15.9
New York		16.2	25.1	4.1
Texas		15.3	39.0	6.0
California		7.3	40.0	2.9
N. Carolina		5.3	0.0	0.0
New Jersey		3.9	20.0	0.8
Ohio		3.8	50.0	1.9
Michigan		2.7	25.0	0.7
Other		28.2	36.4	10.3
Total U.S. cabbage treated				42.6
CELERY	.76			
California		65.7	20.0	13.1
Florida		25.1	100.0	25.1
Michigan		6.0	25.0	1.5
New York		1.8	50.0	0.9
Other		1.4	48.8*	0.7
Total U.S. celery treated				41.3
SNAP BEANS	.74			
Wisconsin		19.3	0.0	0.0
Oregon		18.4	0.0	0.0
New York		14.3	3.0	0.4
Florida		9.2	96.0	8.8
California		5.3	1.0	0.1
Tennessee		4.3	50.0	2.2
Michigan		4.0	10.0	0.4
Other		25.2	22.9	5.8
Total U.S. snap beans treated				17.7
CUCUMBERS	.73			
Michigan		14.8	7.0	1.0
California		11.4	6.0	0.7
N. Carolina		11.0	28.0	3.1
Ohio		6.8	30.0	2.0
Texas		5.7	13.2	0.8
Wisconsin		4.7	1.0	0.05
S. Carolina		4.6	100.0	4.6
Maryland		3.8	20.0	0.8
Other		26.6	32.1*	0.5
Total U.S. cucumbers treated				30.4
CARROTS	.55			
California		47.6	10.0	4.8
Texas		14.2	48.9	6.9
Washington		9.2	0.0	0.0
Michigan		8.4	25.0	2.1
Wisconsin		6.5	50.0	3.3
Other		14.1	26.8*	3.8
Total U.S. carrots treated				20.9

TABLE 3 Continued - 4

Commodity / Site	% in diet[1] of item	% U.S. production[2]	% site treated[3]	% U.S. production treated[4]
DRY BEANS	.50			
Michigan		28.4	2.0	0.6
California		16.3	1.0	0.2
Idaho		15.4	0.0	0.0
Nebraska		11.5	0.0	0.0
Colorado		9.7	0.0	0.0
Other		18.7	0.6*	0.1
Total U.S. dry beans treated				0.9
GREEN PEAS	.49			
Wisconsin		24.4	0.0	0.0
Washington		21.7	0.0	0.0
Minnesota		16.7	0.0	0.0
Oregon		9.4	0.0	0.0
Idaho		4.0	0.0	0.0
Other		23.8	0.0*	0.0
Total U.S. green peas treated				0.0
CAULIFLOWER	.49			
California		71.0	6.0	4.3
New York		10.4	6.0	0.6
Oregon		7.4	6.0	0.4
Arizona		2.3	0.0	0.0
Michigan		1.5	10.0	0.2
Other		7.4	5.6*	0.4
Total U.S. cauliflower treated				5.9
BEETS	.44			
Wisconsin		37.1	1.0	0.4
New York		35.9	0.0	0.0
Texas		6.6	27.8	1.8
Other		20.4	9.6*	2.0
Total U.S. beets treated				4.2
GRAPES	.32			
California		90.0	3.0	2.7
New York		4.3	0.0	0.0
Washington		2.8	0.0	0.0
Pennsylvania		1.4	10.0	0.1
Other		1.5	6.0	0.1
Total U.S. grapes treated				2.9
PEARS	.32			
California		43.4	5.0	2.2
Washington		28.3	0.0	0.0
Oregon		24.5	80.0	19.6
Other		3.8	28.3	1.1
Total U.S. Pears treated				22.9

TABLE 3 Continued - 5

Commodity / Site	% in diet[1] of item	% U.S. production[2]	% site treated[3]	% U.S. production treated[4]
EGG PLANT	.32			
Florida		75.2	50.0	37.6
New Jersey		24.8	60.0	14.5
Other		0.0		
Total U.S. egg plant treated				52.5
SPINACH	.29			
California		57.3	4.0	2.3
Arkansas		4.3	75.0	3.2
Oklahoma		4.3	90.0	3.9
Texas		4.1	100.0	4.1
Colorado		1.8	0.0	0.0
New Jersey		1.7	100.0	1.7
Other		26.5	61.5*	16.3
Total U.S. spinach treated				31.5
PEPPERS	.25			
Florida		35.9	70.0	25.1
California		29.8	2.0	0.6
Texas		11.7	0.0	0.0
New Jersey		8.9	75.0	6.7
Other		13.7	36.8*	5.0
Total U.S. peppers treated				37.4
CHERRIES (sweet and tart)	.17			
Michigan		23.0	0.0	0.0
California		21.1	1.0	0.2
Washington		22.5	0.0	0.0
Oregon		17.5	1.0	0.2
Other		15.9	0.5*	0.1
Total U.S. cherries treated				0.5

[1]Lehman, A. J. 1962. Quart. Bull. Assoc. Food Drug Off. 26(3):149-151.

[2]Based on 1976 crop production statistics of USDA/SRS/CRB (pub). no. CrPr 2-1(77), Vg 1-2(77), Vg 2-2(77), FtNt 1-3(77), and FtNt 3-1(77).

[3]Percent of state's total production of a crop which is treated with any of the EBDC fungicides. Estimates obtained by personal communication with Pesticide Impact Assessment Program State Liaison Coordinators and state Extension Plant Pathologists familiar with current crop production practices in their respective areas. See * below.

[4]Calculated as % U.S. production x % site treated x 100.

*Represents states not sampled, calculated as average of estimates from all sampled states.

TABLE 4. Estimated % total U.S. production of 26 major crops which is treated with any of the EBDC fungicides and the estimated percent of the total contribution to the diet of EBDC treated food items

Food item	Percent in diet of item	Estimated % total U.S. production treated with EBDC	Estimated % contrib. of EBDC treated items to the total diet
Wheat flour	8.05	13.2	1.1
Potatoes	7.00	51.0	3.6
Citrus	4.00	18.7	0.7
Tomatoes	3.34	31.1	1.0
Melons	1.98	46.3	0.9
Apples	1.81	42.2	0.8
Bananas	1.51	1.0	0.02
Sweet corn	1.19	25.0	0.3
Lettuce & escarole	1.15	20.3	0.2
Peaches	1.03	1.8	0.02
Onions	1.01	68.8	0.7
Cabbage & saurkraut	0.91	42.6	0.3
Celery	0.76	41.3	0.3
Snap bean	0.74	17.7	0.1
Cucumber	0.73	30.4	0.2
Carrots	0.55	20.9	0.1
Dry beans	0.50	0.9	0.005
Green peas	0.49	0.0	0.0
Cauliflower	0.49	5.9	0.03
Beets	0.44	4.2	0.02
Grapes	0.32	2.9	0.01
Pears	0.32	22.9	0.01
Eggplants	0.32	52.5	0.2
Spinach	0.29	31.5	0.1
Peppers	0.25	37.4	0.1
Cherries	0.17	0.5	0.001
TOTAL	39.29%		11.01%

If it is assumed that un-surveyed crops for which the EBDC's are registered for use are treated with the same frequency as that shown in this sample, then the contribution to the total diet of EBDC treated food items can be calculated [43% of the total diet shown by Lehman (1962) is represented by crops for which EBDC's are registered].

[11.01% / 39.29%) 43%]100 = <u>12.05% of the total diet treated with EBDC's.</u>

TABLE 5. Calculation of the theoretical daily intake of ethylenebisdithiocarbamate (EBDC) residues by a 60 kg human based on the average values for the amount of food eaten per day (1.5 kg), the established maximum tolerance residues, and estimates of the percent of each food actually treated under current agricultural practice in the United States.

Food item	Food factor(%)[1]	Max. EBDC tolerance (mg / kg)	Est. percent of U.S. production treated	EBDC contribution to daily intake (mg/kg)[2]
Wheat flour	8.05	1 FA	13.2	0.0106
Potatoes	7.00	1 IT	42.7	0.0299
Citrus	4.00	7	18.7	0.0524
Tomatoes	3.34	4	25.9	0.0346
Melons	1.98	4	38.0	0.0301
Apples	1.81	7	42.2	0.0535
Bananas (pulp only	1.51	0.5	1.0	0.0001
Sweet corn	1.19	5	24.0	0.0143
Lettuce & escarole	1.15	25 (romaine)	13.0	0.0374
Peaches	1.03	10	54.7	0.0563
Onions	1.01	7	66.1	0.0467
Cabbage & sauerkraut	.91	10	39.0	0.0355
Celery	.76	5	42.1	0.0160
Snap beans	.74	7	15.0	0.0078
Cucumbers	.73	4	34.3	0.0100
Carrots	.55	7	20.9	0.0080
Dry beans	.50	7	0.9	0.0003
Green peas	.49	7	0.0	0.0000
Beets	.44	7	4.2	0.0013
Cauliflower	.43	10	5.9	0.0025
Grapes	.32	7	2.9	0.0006
Pears	.32	10	22.9	0.0073
Egg plant	.32	7	52.5	0.0118
Spinach	.29	10	31.5	0.0091
Peppers	.25	7	37.4	0.0065
Cherries	.17	7	0.5	0.0001
Total	39.29%			0.4827

FA = food additive IT = interim tolerance

[1] Lehman, A.J. 1962. Quart. Bull. Assoc. Food Drug Off. 26(3):149-151.

[2] Calculation as food factor x max. tolerance x % treated

Quantity of EBDC in diet sampled (39.29% of total diet):

1.5 kg x 0.4827 mg/kg = 0.7241 mg

Theoretical daily intake in diet sampled:

0.7241 mg / 60 kg human = 0.0121 mg/kg of body weight

Extrapolation to total diet:

$$\frac{\text{T.D.I. for sample}}{\text{\% total diet in sample}} \times \text{\% total diet for which tolerances have been established (43\%)}$$

[(0.0121 mg/kg) / 0.3929] x 0.43 = 0.0132 mg/kg of body weight.

TABLE 6. Comparison of maneb tolerance levels and measured residues at harvest on 15 foods.

Food items	Harvest interval	Maneb tol. (mg/kg)	Maximum residue (mg/kg)[1]
Potatoes	NTL	0.1	ND
Tomatoes	5 days	4	0.09
Apples	15 days	2	0.20
Sweet corn	NTL	5	0.20
Lettuce	10 days	10	2.50
Peaches	2 days	10	8.60
Snap beans	4 days	10	5.50
Cucumbers	5 days	4	0.07
Carrots	7 days	2	0.10
Dry beans (lima)	4 days	7	0.00
Cabbage	7 days	10	0.43
Peppers	NTL	7	0.50[3]
Broccoli	3 days[2]	10	7.30
Squash	5 days	4	0.09
Apricot	14 days	10	0.12

NTL = no time limit ND - none detected

1 Residue data provided by E. I. DuPont Co. as extracted from petitions submitted by duPont for the purpose of having tolerances established. Data reported in each case is the maximum residue obtained when maneb was used under the conditions (time limitations) subsequently specified when the tolerance was granted. One exception is noted in footnote 3.

2 3 day interval allowed if broccoli is washed and trimmed.

3 Data excluded was for unwashed peppers collected 30 min. after treatment (5.2 ppm) and from washed peppers in the same test (0.09 ppm).

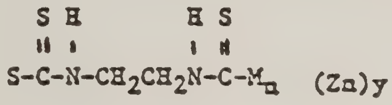
The Transformations of the Ethylenebisdithiocarbamate (EBDC) Fungicides in Biological and Non-biological Systems

Introduction

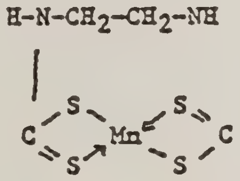
Realistic estimates of human exposure to residues of the EBDC's and ETU by way of dietary intake lead to the conclusions that there is a small but finite level of EBDC and ETU ingested by the population at large. An adequate assessment of the risk associated with dietary intake mustr include evaluation of data and information concerning the transformations of the EBDC fungicides in biological and non-biological systems. This section reviews and summarizes animal metabolism studies, plant metabolism studies, studies on the fate of EBDC fungicides in soil and water, and information on the metabolic fate of ETU. As was true with the dietary exposure section, the toxicological significance of metabolism and transformation of EBDC's is not assessed.

Abbreviations and Codes:

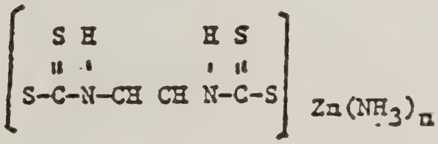
The compounds discussed and abbreviations used are shown below.



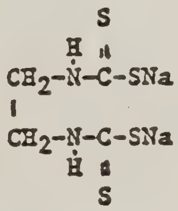
mancozeb
dithane M-45



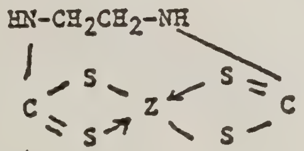
maneb



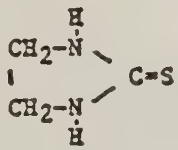
metiram



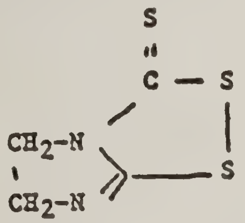
nabam



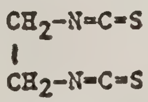
zineb



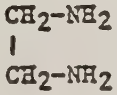
ethylenethiourea
ETU



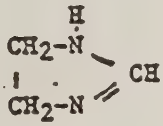
5,6-dihydro-3-H imidazo [2,1-C]-1,2,4-dithiazole-3-thione
DIDT, EBIS



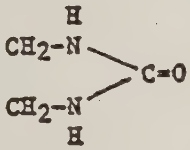
ethylenediisothiocyanate
EDIC



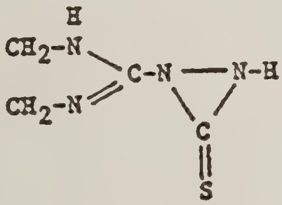
ethylenediamine
EDA



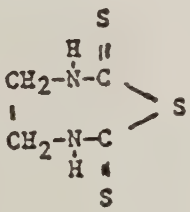
2-imidazoline
IDZ



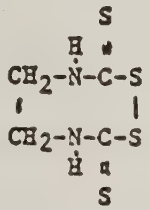
ethyleneurea
EU



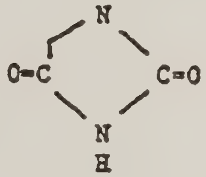
1-(2'-imidazolin 2'-yl) 2-imidazolidinethion
Jaffes Base



ethylene thiuram monosulfide (ETM)



ethylenethiuram disulfide
ETD



hydantoin

Animal Metabolism of EBDC Fungicides

The studies reported by Lyman (1971) are perhaps the most comprehensive investigations of EBDC metabolism in animals that have been published. Rats orally dosed with [ethylene-^{14}C] mancozeb excreted 70.9% of the ^{14}C in the feces and 15.5% in the urine (Table 1). DIDT, EU, and ETU were present in both the urine and feces (Table 2, Figure 1). In addition the urine contained EDA and the acetyl and formyl derivatives of this compound (Table 2, Figure 1). The nature of the radiolabeled residues in the rat tissues one day after the last dose of mancozeb was not determined; however, the concentrations of ^{14}C in the thyroid was several times greater than that of all other tissues and organs analyzed. Only 0.314% of the administered U^{14}C remained in the entire animal when sacrificed one day after the last dose was given (Table 3).

A cow dosed with [ethylene-^{14}C] mancozeb also excreted most of the ^{14}C in the feces and urine (Table 4); this was generally true when the dose given was 1, 5, or 25 ppm (Lyman, 1971). EU and ETU were detected in both the urine and milk from this cow (Figure 1, Table 5). The amount (ppm) of residue in the milk was proportional to the amount of mancozeb fed to a cow (Table 6).

Seidler et al. (1970) dosed rats with [ethylene-^{14}C] maneb and reported that approximately 55% of the ^{14}C was excreted in the feces and urine within 3 days. The excreta contained EDA, ETM,

[illegible] investigation [illegible]

[illegible] found that [ethylene-14C] [illegible]

[illegible] 10.9% of the 14C in the [illegible]

11). [illegible]

[illegible] 11). In contrast the [illegible]

[illegible] and formyl derivatives of this [illegible]

[illegible] nature of the radiolabeled residues [illegible]

[illegible] the last dose of maneb [illegible]

[illegible] of 14C in the thyroid [illegible]

[illegible] of all other tissues and organs analyzed. [illegible]

[illegible] administered 14C remained in the [illegible]

[illegible] day after the last dose [illegible]

[illegible] dosed with [ethylene-14C] maneb [illegible]

[illegible] in the feces and urine [illegible]

[illegible] the dose given [illegible]

were detected [illegible] both [illegible]

[illegible]). The amount (ppm) of [illegible]

[illegible] to the amount of [illegible]

[illegible] et al. (1970) dosed rats with [illegible]

[illegible] that approximately 55% of the [illegible]

[illegible] within 3 days. The excreta [illegible]

ETU (Figure 2), and unknown metabolites. One day after dosing, the rat tissues contained 1.2% of the ^{14}C given.

Rats exhaled CS_2 after being orally dosed with zineb and four metaboalites were excreted in the urine (Truhaut et al., 1973). The two major metabolites in the urine were identified as EDIC and ETU.

Plant Metabolism of EBDC Fungicides

Although nabam is apparently no longer used extensively in agriculture practices, the metabolism of this compound has been studied extensively. Since it is similar to the other EBDC fungicides a discussion of the metabolism of nabam is justified. Vonk (1975) applied ^{14}C-labeled nabam to the roots and leaves of cucumber seedlings. After root treatment for 2 days, most ^{14}C-activity in the green parts of the plant was water soluble; however, considerable activity was also present in the roots and the insoluble fraction of the green parts of the plant (Figure 4). The water extracts contained ETU, DIDT, EU, IDZ (Figure 5) and other unidentified compounds (Figure 4). During the post-treatment period the concentration of ETU gradually decreased and the concentration of EU and IDZ gradually increased. Only 22-31% of the ^{14}C-activity in the plants was identified.

Most of the radioactivity present 2 weeks after leaf application of ^{14}C-nabam which could be removed by washing contained ETU, DIDT, and an unidentified polar compound(s). Extracts of the treated leaves contained ETU, IDZ, and an unidentified polar compound(s). Sijpesteijn et al. (1977) have proposed a series of metabolic transformations to account for the metabolites of nabam (Figure 6).

EDIC, ETU, DIDT, and sulfur were observed on the fruit of tomato plants treated with maneb (Figure 7). Newsome (1975) measured the residues of maneb, ETU, DIDT, and EDA on beans and tomatoes from 0 to 14 days after treatment with maneb. The residues were higher for beans than tomatoes but in both cases the residues declined with time. After 14 days, beans contained the following amounts (ppm) of the compounds: maneb 13; ETU 0.11; DIDT 0.25; EDA 0.09. The corresponding values for tomatoes were: maneb 10; ETU 0.07; DIDT 0.03; and EDA 0.05. Rhodes (1977) reported that ^{14}C-residue(s) could not be identified. Sato and Tomizawa (1960) reported that ETU and an unidentified compound(s) was present on cucumber leaves after the application of [^{35}S] zineb. Engst et al. reported that EDIC, ETU, DIDT, and sulfur were present on tomato plants after treatment with zineb.

Lyman treated sugar beets, lettuce, and turnips with [^{3}H]-mancozeb and observed a number of radiolabeled metabolites that included EU, EDA, IDZ, DIDT, ETU, and Jaffes Base and the parent

compound mancozeb. The percentage of the total radioactivity represented by these compounds is shown in Table 7.

In a recent report, Pease and Holt (1977) indicated that ETU residues in tomatoes, potatoes, cucumbers, summer squash, and cantaloupes taken from 17 different locations throughout the United States were less than 0.05 ppm even in the presence of up to 4 ppm of maneb.

EBDC and Related Residues in Plant Materials

Because of the concern over human consumption of the EDBC fungicides and/or their breakdown products, a number of residue studies have been conducted. Some of the more comprehensive studies have been reported by Newsome et al. (1976). For instance, there was a gradual decline in the residues of the parent compound on tomatoes during a 14-day period after treatment with mancozeb, Manzate D, Polyram 80-W, or zineb 75W (Newsome, 1976) as shown in Table 8. There was an initial increase and then a gradual decrease in the residues of ETM and EDIC as shown in Table 9. Another representative study showing the residues of mancozeb and ETU in apples and apple products is summarized in Table 10.

There is evidence that the conditions required to cook and process foods result in the conversion of the EBDC fungicides and/or metabolites to ETU. For instance, boiling tomatoes that had been sprayed with EBDC fungicides incresed the ETU concentration as shown

in Table 11. A similar study showed that processing tomatoes, carrots, and spinach resulted in lower EBDC residues but higher ETU residues (Table 12).

The Fate of EBDC Fungicides in Soil and Water

Nabam decomposes in aqueous solutions to ETU, DIDT polymers ethylenethiuron disulfide, EDA, EDIC sulfur, CS_2 and H_2S (Sijpesteijn et al. 1977). Vonk (1975) reported that ETU and DIDT were the main degradation products when ^{14}C-nabam was dissolved in water. Maneb and zineb repoortedly degrade to the same group of compounds outlined for nabam (Sijpesteijn et al. 1977).

In soil, EDA, ETU, DIDT, CS_2, and H_2S are formed from nabam (Sijpesteijn et al. 1977; Sijpesteijn and Vonk, 1970). Studies by Iley and Fiskell (1963) suggest that zineb was at least partially degraded by sunlight and soil cultures. Nash (1976) reported that when soil was treated with ^{14}C-labeled nabam, zineb and maneb, the radioactivity was readily absorbed by soybeans and translocated through the plant. Radioactive compounds in the plant included Jaffe's Base, hydantoin, EU, ETU, and N,N-dimethylene-5-imino-1,2-dithio-4-azolidine-3-thione. The metabolite profile was similar regardless whether the EBDC fungicides were sprayed onto the leaves or injected into the soil. Vonk and Sijpesteijn (1976) reported that microorganisms readily converted DIDT to ETU.

[illegible] [illegible] ind. [illegible] [illegible] [illegible]

[illegible] a compound [illegible] from [illegible]. [illegible] and

es (Table [illegible]).

[illegible]ompounds in aqueous solutions [illegible] [illegible]

uron diuolido, DDA, [illegible] [illegible] [illegible]

casteiio et al. 19[illegible]). [illegible] (19[illegible]) reported [illegible]

a [illegible] main degradation products when [illegible]

[illegible]. [illegible] and [illegible] reportedly degrade [illegible]

pounds outlined for [illegible] [illegible] et al. [illegible]

soil, [illegible], [illegible], [illegible], [illegible], and [illegible] are formed [illegible]

[illegible] et al. 197[illegible] [illegible] and [illegible], 197[illegible]

dies by Iley and Fixell (1961) suggest that [illegible] [illegible]

degraded by sunlight and soil cultures. [illegible] (19[illegible]) [illegible]

[illegible] that when soil was treated with [illegible]-labeled [illegible], [illegible]

[illegible], the radioactivity was readily absorbed by [illegible] [illegible]

[illegible] through the plant. Radioactive compounds in the plant

[illegible]'s base, [illegible], [illegible] [illegible]-[illegible]-

[illegible]-[illegible]-one. The metabolic [illegible] was

[illegible] regardless whether the [illegible] fungicide were sprayed onto the

or [illegible] [illegible] the soil. [illegible] and [illegible] (19[illegible])

[illegible] microorganisms [illegible] [illegible] to [illegible].

Metabolic Fate of ETU

Newsome (1974) reported that 50% of the ETU administered (20 mg/kg) to rats and guinea pigs was excreted unchanged in the urine within 24 hours. Lyman (1971) dosed a cow with ^{14}C-labeled ETU and reported that EU, EDA, oxalic acid, glycine, and urea were major radioactive metabolites in the urine and milk (Table 13). EU and IDZ were identified as plant metabolites of ETU (Vonk, 1975). Nash (1976) reported the presence of 7-10 different degradation products in methanol extracts of soybeans treated with ETU; EU was the major metabolite identified.

ETU was converted to at least 9 different products (Cruickshank and Jarrow, 1973) by photo-oxidation; the major product (EU) and Jaffe's Base were identified. Other photo-oxidation products of ETU that have been reported include IDZ (Vonk, 1975) and glycine (Ross and Crosby, 1973). In the absence of ultraviolet light, ETU was quite stable (Ross and Crosby, 1973).

ETU was degraded more slowly in autoclaved soil than in non-sterile soil (Kaufman and Fletcher, 1973); CO_2 ethylene urea, hydantoine, Jaffe's Base and other unidentified products were detected.

The metabolism of ETU on biological and non-biological systems has been summarized by Kearney et al. 1977, as shown in Figure 10.

It is apparent that animal, plant and soil metabolism as well as photochemical decomposition of ETU results in many of the same compounds.

Summary and Conclusions

(1) The biological and non-biological transformations of the various EBDC fungicides are similar. The information available indicates that they are converted to a series of metabolites that includes DIDT, ETU, IDZ, EU, EDIC, and ETM.

(2) The primary metabolism of the EBDC fungicides is similar in plants, animals, soil, and water. Similar transformation also results from photodecomposition.

(3) ETU is a primary metabolite of EBDC fungicides in plants, soils, animals, and water.

(4) ETU is metabolized (or transformed non-biologically) to a number of metabolites that includes EU, IDZ, hydantoin, Jaffe's Base, glycine, oxalic acid, CO_2, EDA, urea, natural products, and other unknown compounds.

(5) The metabolism of ETU in plants and animals is similar.

(6) Residues of the EBDC fungicides and some of their metabolites including ETU have been measured on food plants grown under field conditions.

(7) EBDC residues, if present in or on food items, are at least partially converted to ETU by cooking and other types of heat processing.

Table 1. ^{14}C-labelled Dithane M-45 material balance in rats[a,b]

Material	^{14}C, percentage of total dosage
Feces	70.90
Urine	15.50
Cage washings	3.98
Intestinal washings	0.18
Organ and tissue samples	0.31
Carcasses	0.96
Total recovery	91.83

(a) Six rats were orally dosed with 20 mg of ^{14}C-labelled Dithane M-45 each day for seven days. The rats were killed one day after the last dose.

(b) W.R. Lyman in Pesticide Terminal Residues (A.S. Tahori, ed) Butterworths, London pp 243-256 (1971)

Table 2. Percentage of ^{14}C activity in rat excreta present as known transformation products of Dithane M-45[a]

Material	Percentage of urine ^{14}C	Percentage of Feces ^{14}C	Percentage of recovered ^{14}C
Dithane M-45	-	47.0	36.8
EBIS	5.6	7.5	7.1
ETU	28.0	6.0	10.8
EU	12.0	2.0	4.1
N-Acetyl EDA	19.0	-	4.1
N-Formyl EDA	1.0	-	0.1
EDA	3.5	-	0.7
	69.1	62.5	63.7

[a] Rats were orally dosed with 20 mg of ^{14}C-labeled Dithane M-45. Compounds were identified by reverse isotope dilution.

[b] W.R. Lyman in Pesticide Terminal Residues (A.S. Tahori, ed) Butterworths, London pp 243-256 (1971)

TABLE 3. Analysis of rat tissues by radioassay[a,b]

Tissue sample	Percentage of total dose given	Total wt (g)	Amount as Dithane M-45, p.p.m
Muscle	0.014	17.3	6.8
Fat	0.010	10.7	7.4
Liver	0.193	65.6	24.8
Kidney	0.076	12.6	51.6
Thyroid	0.003	0.032	865.0
Heart	0.005	5.45	8.2
Brain	0.003	9.67	2.2
Spleen	0.007	5.29	10.7
Total	0.314		

(a) Rats were orally dosed with 20 mg of ^{14}C-labeled Dithane M-45 each day for seven days. The rats were killed one day after the last dose. This corresponded to 1000 ppm in the diet.

(b) W. R. Lyman in Pesticide Terminal Residues (A. S. Thori, ed) Butterworths, London pp 243-256 (1971).

TABLE 4. ^{14}C-labelled Dithane M-45 material balance in cows[a,b]

Dose (p.p.m.)	Residue in excreta (p.p.m., as Dithane M-45)			Recovery (per cent)
1	Urine	0.50		13.9
	Feces	0.47		86.1
			Total	100.0
5	Urine	4.75		31.6
	Feces	1.49		54.4
			Total	86.0
25	Urine	19.7		32.8
	Feces	10.4		68.2
			Total	101.0

[a] A cow was dosed twice daily for three successive 14 day periods at 1 ppm, 5 ppm, and 25 ppm in the diet.

[b] W. R. Lyman in Pesticide Terminal Residues (A. S. Tahori, ed) Butterworths, London pp 243-256.

TABLE 5. ^{14}C-activity in the milk and urine of cows fed 25 ppm ^{14}C-Dithane M-45[a,b,]

Substance	Milk		Urine	
	p.p.m	Percentage of ^{14}C	p.p.m	Percentage of ^{14}C
Ethylene thiourea	0.03	23	0.06	0.84
Ethylene urea	0.01	10	0.79	12
Urea	-	-	-	3
Oxalic acid	-	-	-	3
Glycine	-	-	-	12
Fat	-	5	-	-
Protein	-	7	-	-
Lactose	-	15	-	-

(a) Dithane M-45 = Mancozeb

(b) W. R. Lyman in Pesticide Terminal Residues (A. S. Tahori, ed) Butterworths, London pp 243-256 (1971)

TABLE 6. ^{14}C in milk versus dose level[a,b,]

Dose (p.p.m.)	Residue in milk (p.p.m.)	Ratio $\frac{\text{p.p.m. (milk)}}{\text{p.p.m. (dose)}}$
1.0	0.014	0.014
5.0	0.066	0.013
25.0	0.390	0.016

(All values are calculated as Dithane M-45)

[a] A cow was dosed twice daily for three successive 14-day periods at 1 ppm, 5ppm, and 25 ppm in the diet

[b] W. R. Lyman, Pesticide Terminal Residues (A. S. Tahori, ed) Butterworths, London pp 243-256

Table 7. Compounds detected in Plant residues two weeks sfter application of labeled Cithane M-45[a,b]

Compound	Percentage of ^{3}H activity
Ethylene urea	17
Ethylenediamine	11
Dithane M-45	9
2-Imadazoline N-Formyl ethylene diamine	8
Ethylene bisisothiocyanate sulphide	7
Ethylene thiourea	6
Jaffe's Base	4
Total	62 (of = 200 ppm as Dithane M-45)

[a]Dithane M-45 = Mancozeb

[b]W. R. Lyman in Pesticide Terminal Residues (A. S. Tahori, ed) Butterworths, London pp 243-256 (1971)

Table 8. Residues[a] of ethylenebisdithiocarbamate on tomatoes at various intervals after application by spraying[b]

Elapsed Time (days)	Mancozeb	Manzate D	Polyram 80-W	Zineb 75W
0	8.96 ± 0.50	13.0 ± 1.89	3.22 ± 0.13	4.78 ± 0.13
1	10.9 ± 0.56	9.40 ± 0.92	3.45 ± 0.28	3.68 ± 0.26
2	9.23 ± 0.60	8.31 ± 0.87	3.58 ± 0.32	4.00 ± 0.17
3	9.15 ± 0.40	6.26 ± 0.58	2.54 ± 0.10	5.24 ± 0.12
6	4.08 ± 0.32	3.08 ± 0.28	1.43 ± 0.11	1.50 ± 0.06
10	3.92 ± 0.13	3.82 ± 0.17	1.30 ± 0.09	1.83 ± 0.15
14	3.29 ± 0.17	3.20 ± 0.13	0.778 ± 0.04	1.27 ± 0.06
Control	0.141 ± 0.014			

[a]Values (in ppm) are the means ± S. E. of 6 samples and are expreessed as zineb.

[b]Newsome (1976) as reported by Kearney *et al*. Pure and Applied Chem 49: 675-689 (1977).

Table 9. Residues[a] of ethylenethiuram monosulfide and ethylenebis (isothiocyanate) on tomatoes treated with ethylenebisdithiocarbamates in the field[b]

Elapsed Time (days)	Mancizeb	Manzate D	Polyram 80-W	Zineb 75W
	Ethylenethiuram Monosulfide Found (ppm)			
0	0.019 ± 0.009	0.066 ± 0.018	0.008 ± 0.002	0.009 ± 0.002
1	0.032 ± 0.003	0.041 ± 0.005	0.020 ± 0.004	0.008 ± 0.001
2	0.035 ± 0.001	0.025 ± 0.001	0.012 ± 0.002	0.014 ± 0.004
3	0.017 ± 0.001	0.027 ± 0.001	0.007 ± 0.002	0.003 ± 0.001
6	0.019 ± 0.001	0.020 ± 0.001	na	na
Control	0.004 ± 0.002			
	Ethylenebis(isothiocyanate) Found (ppm)			
0	0.009 ± 0.002	0.011 ± 0.001	0.007 ± 0.0	0.002 ± 0
1	0.016 ± 0.002	0.16 ± 0.003	0.006 ± 0.001	0.003 ± 0.001
2	0.013 ± 0.001	0.015 ± 0.001	0.002 ± 0.001	0
3	0.014 ± 0.002	0.013 ± 0.001	0.005 ± 0.001	0
6	0.003 ± 0.001	0.016 ± 0.001	na	na
Control	0.002 ± 0			

[a]Values are the means ± S.E. of 6 samples

[b]Newsome (1976) as reported by Kearney *et al.* Pure and Applied Chem 49: 675-689 (1977)

Table 10. Residues (ppm) of EBDC's/ETU on apples and apple products[a]

Apples	Mancozeb	ETU	Metiran (80 W)	ETU
Before last application	4.2	0.05	0.90	0.03
After last application	12.8	0.05	12.50	0.17
2 days after	11.6	0.06	13.20	0.14
7 days after	11.1	0.05	7.00	0.07
14 days after	6.6	0.06	3.30	0.07
28 days after	3.1	0.03	1.20	0.03
42 days after	1.7	0.01	0.50	0.01
Apple juice	ND	0.05	ND	0.05
Apple pomace	14.90	0.17	3.30	0.15
Apple sauce	0.09	0.05	0.09	0.04

Four precover sprays of 2 lb/100 gls followed by 5 cover sprays of 1.5 lb/100 gallons. Apples ground and pressed at 3000 psi, racked, filtered, and heated to 93°C for 2 min. and canned.

Residue from juice extraction dried at 150°C for 15 hours.

Apples peeled, - into 2% saline solution, diced, drained. Heated to slow boil (100°C) and held for 5 min. Canned and heated in boiling water for 15 min.

[a] F. A. Wood (1976) as reported by Kearney _et al_. Pure and Applied Chem. _49_: 675-689 (1977).

Table 11. Effect of cooking on ethylenethiourea residues in tomatoes sprayed with ethylenebisdithiocarbamates[a]

Time After Spraying (days)	Mancozeb M-45	Manzate D	Polyram 80-W	Zineb 75W
		Uncooked		
0	0.036 ± 0.004	0.033 ± 0.004	0.025 ± 0.005	0.033 ± 0.005
1	0.065 ± 0.015	0.018 ± 0.002	0.085 ± 0.015	0.024 ± 0.003
3	0.036 ± 0.009	0.026 ± 0.003	0.006 ± 0.003	0.007 ± 0.001
6	0.017 ± 0.004	0.015 ± 0.001	0.039 ± 0.004	0.006 ± 0.003
14	0.011 ± 0.001	0.008 ± 0.001	0.009 ± 0.002	0.011 ± 0.006
Control	0.001 ± 0.001			
		Boiled 10 min.		
0	1.14 ± 0.080	1.11 ± 0.138	0.217 ± 0.026	0.772 ± 0.144
1	1.33 ± 0.134	1.42 ± 0.162	0.754 ± 0.162	0.950 ± 0.117
3	1.08 ± 0.140	0.945 ± 0.173	0.584 ± 0.052	0.535 ± 0.080
6	1.03 ± 0.127	0.462 ± 0.051	0.174 ± 0.016	0.206 ± 0.005
14	0.935 ± 0.142	0.519 ± 0.049	0.184 ± 0.015	0.110 ± 0.007
Control	0.020 ± 0.002			

[a]Newsome (1976) as reported by Kearney *et al*. Pure and Applied Chem. 49: 675-689 (1977)

Table 12. Summary of EBDC - ETU residues (ppm) before and after processing [a]

	Eastern USA		Western USA	
Tomato	EBDC	ETU	EBDC	ETU
Unwashed	0.3	—	2.1	0.01
Washed	0.2	—	0.6	0.01
Canned	—	0.03	0.5	0.11
Carrots				
Unwashed	0.6	—	0.1	0.01
Washed	0.3	—	0.1	0.01
Diced	0.1	—	0.1	—
Frozen	—	—	—	—
Canned	—	0.03	0.1	—
Spinach				
Unwashed	2.4	—	61.9	0.34
Washed	1.5	—	9.7	0.02
Frozen	0.1	0.04	0.6	0.50
Canned	—	0.18	0.1	0.71

Mancozeb was applied at the rate of 0.7 ai/0.5 ha in all cases. Spray schedules were as follows: spinach, 1 treatment with 10 day pre-harvest interval; carrot-eastern, 6 treatments at 7-10 day intervals, pre-harvest interval 7 days. Tomato-eastern, 4 treatments at 7-10 day intervals, pre-harvest interval 16 days. Tomato-western, 3 treatments at seven day intervals, pre-harvest interval 5 days.

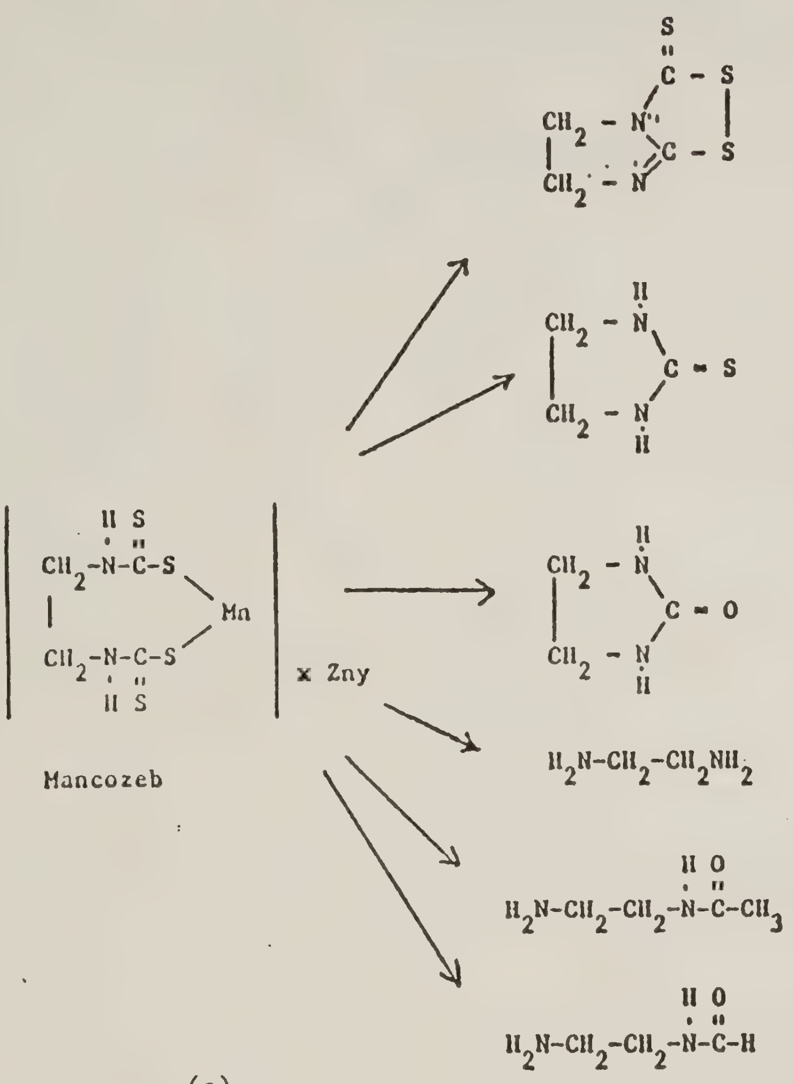
(a) W.Phillips Interim report from Technological Resources Inc. to the U.S. Environmental Protection Agency as reported by Kearney *et al*. Pure and Applied Chem. 49:675-689 (1977)

Table 13: ^{14}C activity in the milk and urine of cows fed with 1 p.p.m. of [^{14}C]ethylene thiourea[a]

Material	Conc. (p.p.m.)	Milk % of total ^{14}C	Conc. (p.p.m.)	Urine % of total ^{14}C
Ethylene thiourea	0.011	31	0.12	7
Ethylene urea	0.0025	8	0.27	18
Ethylenediamine	-	-	0.14	14
Glycine	-	-	-	6
Oxalic acid	-	-	-	12
Urea	-	-	-	11
Fat	-	3	-	-
Protein	-	18	-	-
Lactose	-	16	-	-
Totals (per cent)		76		68

[a] W.R. Lyman in Pesticide Terminal Residues (A.S. Tahori, ed) Butterworths London pp 243-256 (1971)

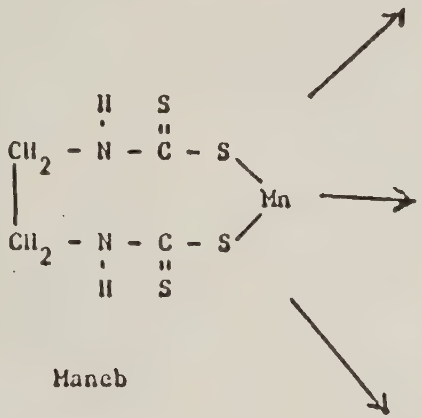
Figure 1. Animal Metabolites of Mancozeb[a]



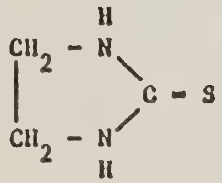
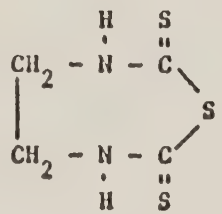
Source	Evidence for structure	Reference
Rat urine and feces	Reverse isotope dilution	a
Rat urine and feces; Cow urine and milk	Reverse isotope dilution	a
Rat urine and feces; Cow urine and milk	Reverse isotope dilution	a
Rat urine	Reverse isotope dilution	a
Rat urine	Reverse isotope dilution	a
Rat urine	Reverse isotope dilution	a

[a] W. R. Lyman, International Symposium on Pesticide Terminal Residues Tel-Aviv.

Figure 2. ANIMAL METABOLITES OF MANEB

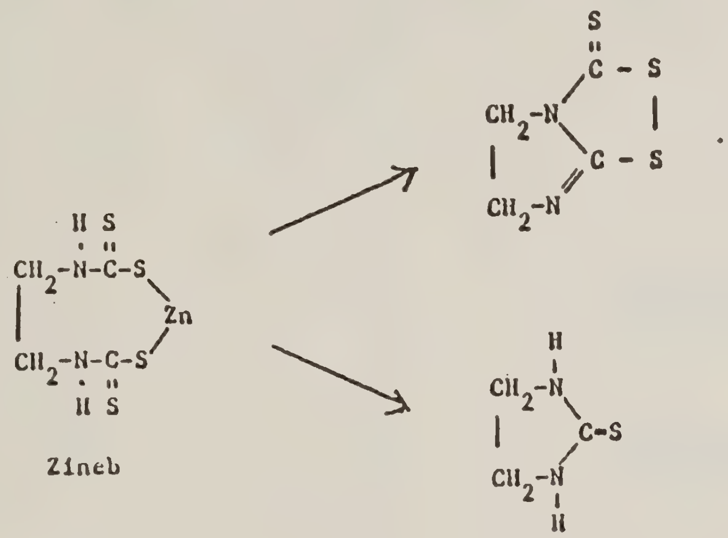


Maneb

Proposed structure	Source	Evidence for structure	Reference
$H_2N-CH_2CH_2-NH_2$	Rat urine and feces	Comparative chromatography	a
	Rat urine and feces	Comparative chromatography	a
	Rat urine and feces	Comparative chromatography	a

(a) H. Seidler et al. Nahrung 14:363 (1970)

FIGURE 3 METABOLITES OF ZINEB IN ANIMALS



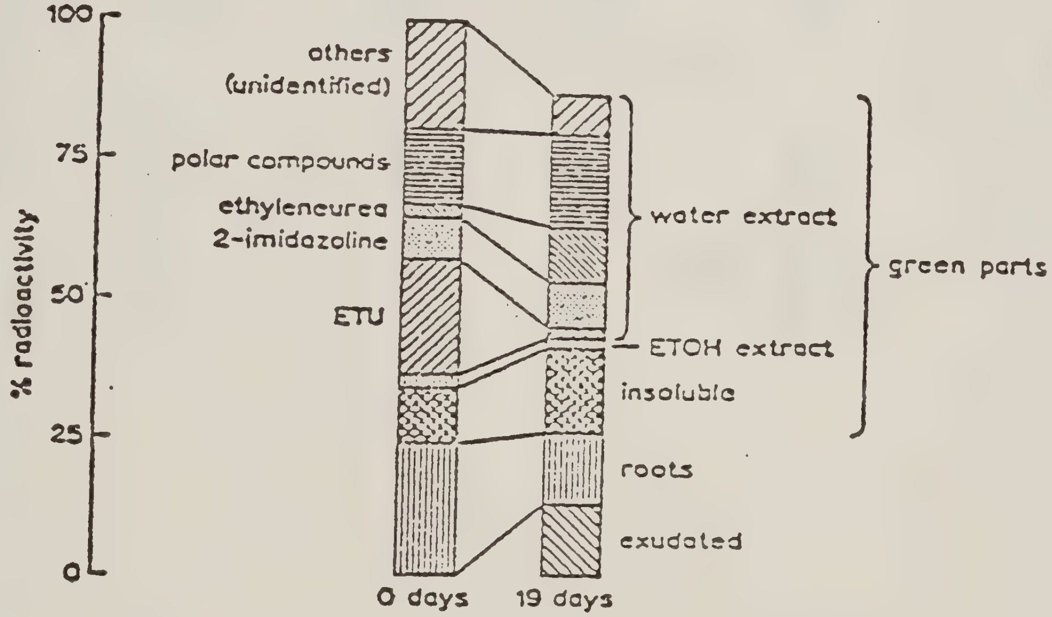
Zineb

Source	Evidence for structure	Reference
Rat urine	comparative spectrometry	a
Rat urine	comparative spectrometry	a

(a) Truhaut et al. C.R. Hebd Seanc Acad Sci Paris (D) 276, 229 (1973)

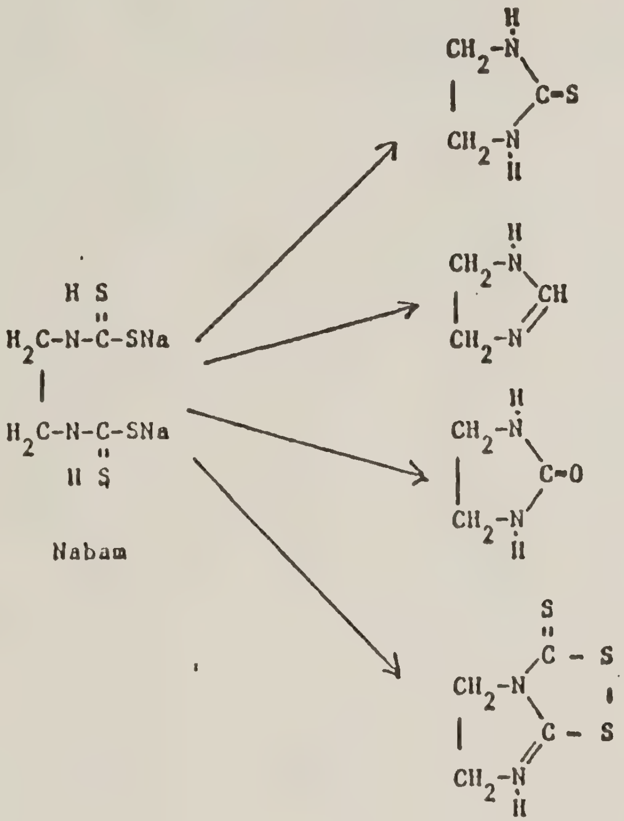
FIGURE 4.

The Distribution of Radioactivity among the Different Parts, Fractions and Compounds in Cucumber Seedlings 0 and 19 days after Root Treatment with [^{14}C] Nabam[a]



(a) A. Kaars Sizpesteizn, H. M. Dekhuizzen and J. W. Vonk <u>Antifungal Compounds Volume 2</u> M. R. Siegel and H. D. Sisler, Editors, Marcel Dekker, 1977.

FIGURE 5. METABOLITES OF NABAM IN PLANTS AND SOIL

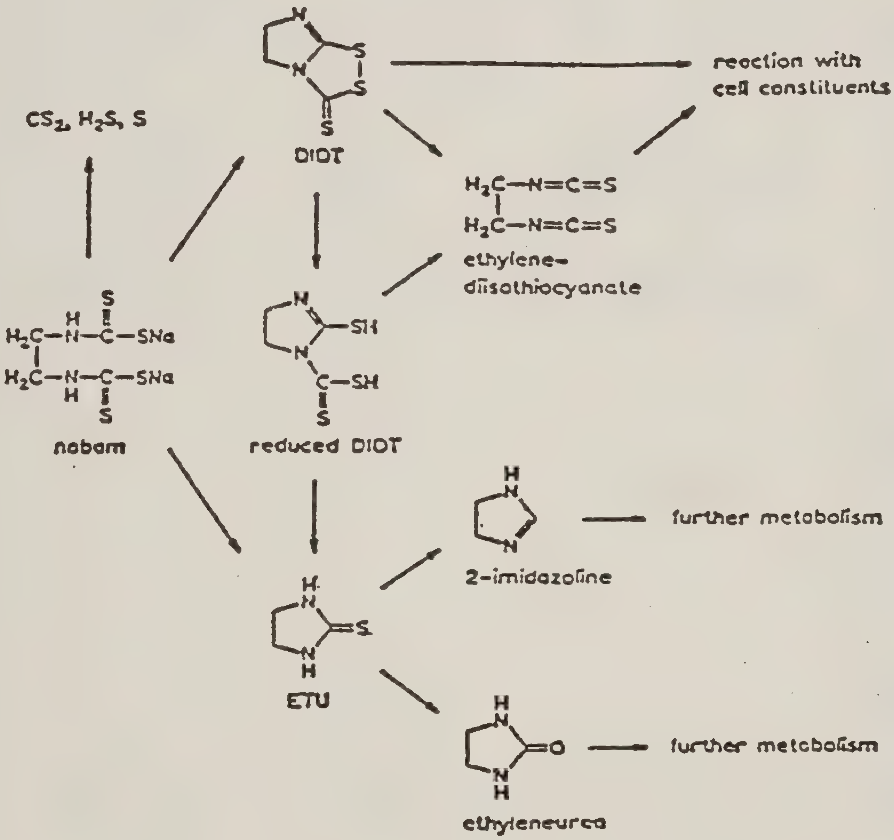


Source	Evidence for structure	Reference
cucumber plant	comparative chromatography	a
soil		b
cucumber plant	comparative chromatography	a
cucumber plant	comparative chromatography	a
cucumber plant	comparative chromatography	a
soil		b

(a) J.W. Vonk, Ph.D. Thesis, University of Utrecht (1975)

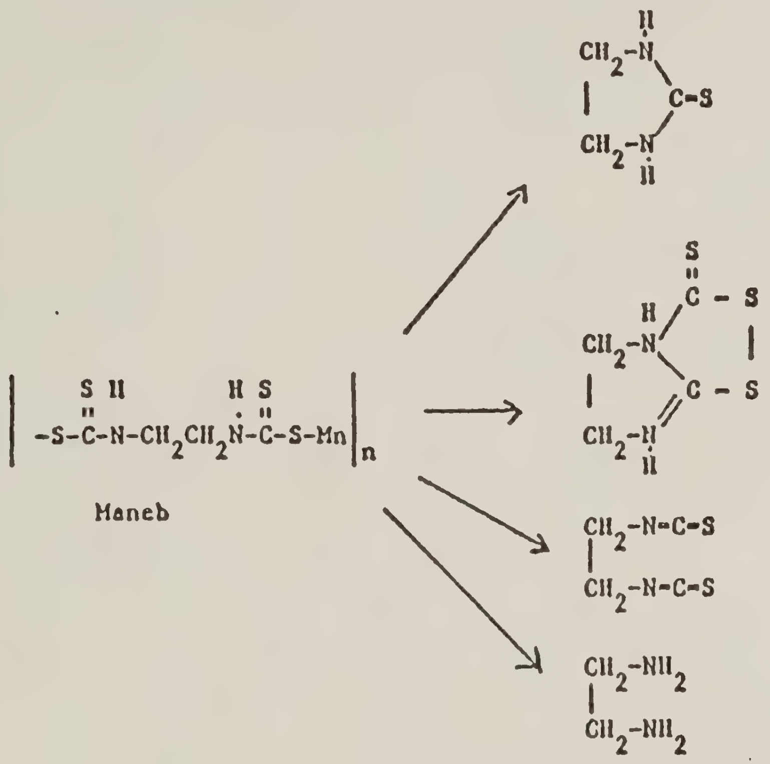
(b) Sijpesteizn *et al*. Antifungal Compounds, Volume 2 pp 91-147 (1977)

Figure 6. Transformations involved in metabolism of nabam by plants and microorganisms[a]



[a]Reference 5 A. Kaars Sizpesteizn, H.M. DeKhuizzen and J.W. Vonk <u>Antifungal Compounds</u> M.R. Siegel and H.D. Sisler, Editors; Marcel Dekker Inc. NY 1977.

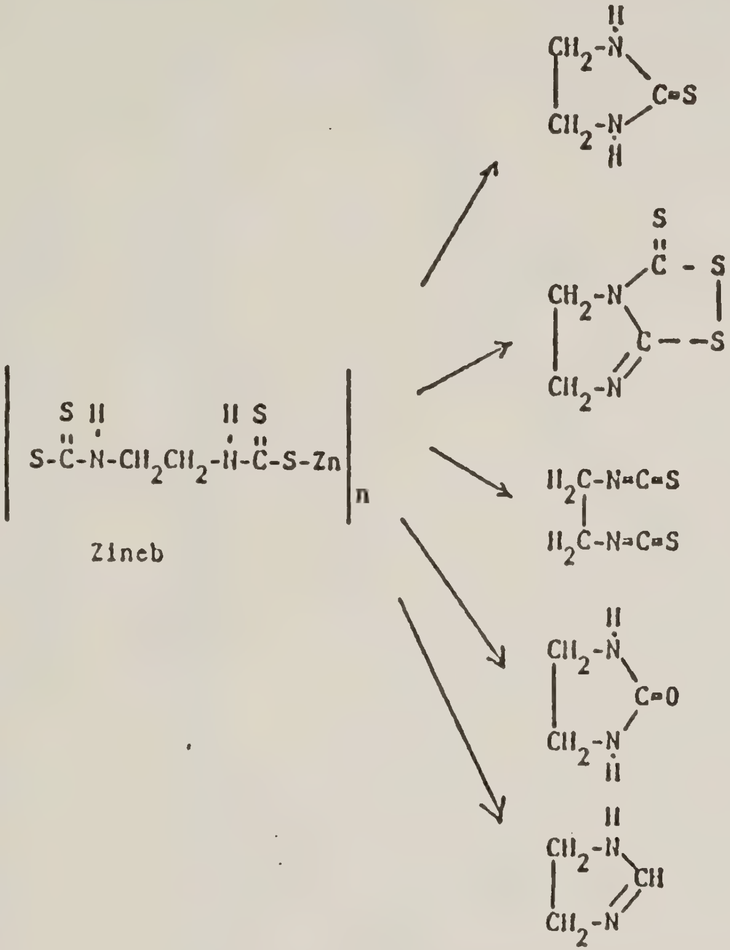
Figure 7. Metabolites of Maneb in Plants



Proposed Structure	Source	Reference
	lettuce	a
	kale	a
	tomato plants	c
	beans	d
	tomato plants	b
	tomato plants	c
	beans	d
	tomato plants	b
	tomato plants	c
	tomato plants	c
	beans	d

(a) J.W. Vonk, Modedel Rizksfoc. Landbouwwetenschap Gent 41: 1883 (1976).
(b) R. Engst, W. Schnaak and H. Rattba, Nachrbl. Deut. Pflanzenschutzdienst (Berlin) 22:26 (1968)
(c) W.H. Newsome, J. Agr. Food Chem. 24:999 (1976)
(d) W.H. Newsome, J.B. Shields and B.C. Villeneuve, J. Agr. Food Chem. 23:756 (1975)

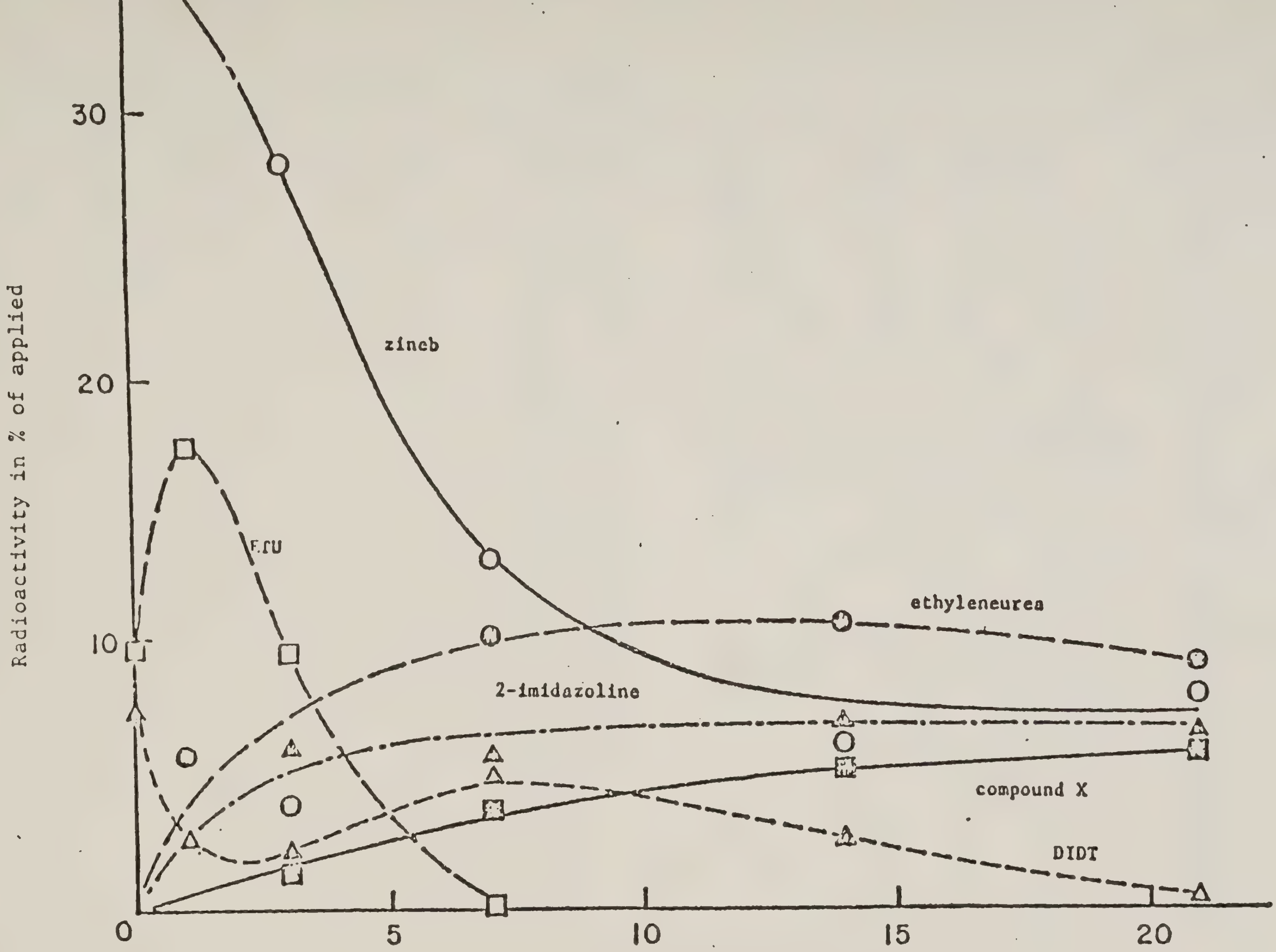
Figure 8. Plant and Microorganism Metabolites of Zineb



Proposed Structure	Source	Reference
(1)	cucumber plant	a
	tomato plants	b
	lettuce	c
(2)	tomato plants	b
	lettuce	c
(3)	tomato plants	b
(4)	lettuce	c
(5)	lettuce	c

(a) T. Sato and Tomizawa Bull Natl Inst Agr Sci Ser C., 12:181 (1960)
(b) R. Engst, W. Schaak and H. Rattba; Nachrbl. Deut. Pflanzenschutzdienst (Berlin) 22:26 (1968)
(c) J.W. Vonk; Mededel Rizksfac. Landbouwwetschap Gent, 41:1883 (1976)

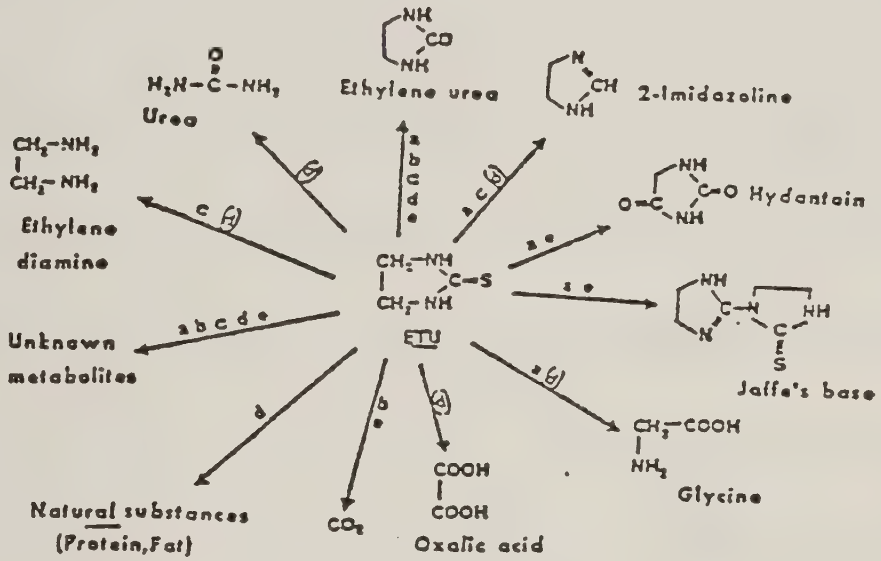
Figure 9. Transformation of zineb on lettuce during 3 weeks.[a]



[a] J.W. Vonk, Med. Fac. Landbouuw. Rijksuniv Gent <u>41</u>: 1383 (1976).

Figure 10.

Reaction Products of ETU in Biological and Non-Biological Systems[a,b]



(a)Kearney et al. Pure and Applied Chem 49:675-689 (1977)

(b)a=photodecomposition, b=chemical oxidation, c=plants, d=animals, and e=soil. Letters in parenthesis ( ) indicate proposed pathways.

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DRAFT

Assessment of Ethylenebisdithiocarbamate (EBDC)
Fungicide Uses In Agriculture

USDA/State/EPA Assessment Team

Part II. An Analysis of Current EBDC Uses; Their Benefit, the Role of Alternatives, and Impacts to Agriculture from Changes in EBDC Use Patterns

Coordinated by the Office of
Environmental Quality Activities
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September, 1978

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OVERALL SUMMARY AND CONCLUSIONS

Since their introduction in the mid-1940's, ethytlenebisdithiocarbamate (EBDC) fungicides have become the most widely used disease prevention chemicals in the production of food in the United States and in the World. Major agricultural uses in the United States are in the production of potatoes, tomatoes, other vegetables, apples, and certain cereal grains. When totaled the six EBDC products have registrations for 1,296 site-pest combinations. Many small volume uses exist for which there are no suitable alternatives. These uses occur for "speciality" or "minor" crops as well as major crops. EBDC are essential because the fungicides have broad spectrums of activities, do not promote pathogen resistance, are relatively non-phytotoxic, and are inexpensive relative to alternatives.

Vegetables

Fungicidal sprays are used to control four major foliar pathogens of tomatoes which are *Alternaria solani* (Ellis & G. Martin) Jones & Grout, *Cladosporium fulvum* Cooke, *Stemphylium solani* Weber, *Phytophthora infestans* (Mont) deBary. In 1976, eleven states planted 109,800 acres of which 72,035 were treated with EBDC fungicides. The number of applications to fresh market tomatoes ranged from 4 to 22 at a rate of 1.2 - 2.4 lb. active ingredient (a.i.) per acre per application.

The EBDC fungicides (maneb and mancozeb) have been effective in the control of major diseases of processing tomatoes for many years. They are the most widely used fungicides on tomato acreage for processing in the Eastern United States.

The loss of registration of these fungicides or severe restrictions on their use for tomato disease control would increase the cost of production because of the higher cost of the alternative fungicide. This increased cost would make it extremely difficult for the tomato processing industry in the East to remain competitively viable.

The most serious diseases of sweet corn which are controlled with EBDC in the United States are northern leaf-blight caused by Helminthosporium turcicum Passerini, southern leaf-blight caused by Helminthosporumium maydis Nisik and Miyake, and corn rust caused by Puccinia sorghi Schweinitiz. EBDC fungicides are the key chemicals used on 97.6% of grower sweet corn disease control programs. Sweet corn yields averaged 49.0 cwt per acre during the 10 years prior to widespreads use of EBDC fungicides. The first 10 years of EBDC fungicide use, yields increased some 71.6 cwt per acre.

Bean anthracnose (Colletotrichum lindemuthianum Saccardo and Magnus) Scribner and bean rust (Uromyces phaseoli typica Arthur) are serious diseases of snap beans which are controlled with EBDC fungicides. In 1976, 339,000 acres of snap beans were planted in

the United States (U.S.). EBDC fungicides are a major part of all grower disease control programs on snap beans. During the 10 years prior to widespread use of EBDC fungicide on snap beans, an average yield was 29.0 cwt per acre. The following 10 years with EBDC fungicide use the yield rose 10.7% to 32.1 cwt per acre.

Early-blight (Cercospora apii - Fresenius) and late-blight (Septoria apii Chester and Septoria apii - graveolentis Dorogin) are the most serious diseases of celery which are controlled with EBDC fungicides. In 1976, 34,910 acres of celery were planted in the U. S. In Florida 10,900 acres were planted and all were treated with EBDC fungicides. EBDC fungicides are used by 97% of all celery growers in their disease control programs. During the 10 years prior to widespread use of EBDC on celery, yields averaged 295.4 cwt per acre. They have risen to 388.4 cwt per acre during the following 10 years.

Phytophthora blight (Phytophthora capsici Leonian), frogeye spot (Cercospora capsici Heald and Wolf), and anthracnose (Gloeosporium piperatum Eli. and Ev.) are diseases on peppers having varying degrees of importance throughout the U. S. All three disorders are generally controlled with EBDC fungicides.

In 1976, 57,400 acres of peppers for fresh market and processing were planted in the U. S. Maneb, maneb plus zinc and zineb are used extensively for the control of Phytophthora blight, frogeye

spot, and anthracnose. Copper fungicides are the only alternatives, and these are only recommended for frogeye spot. The EBDC fungicides are a major part of all pepper grower disease control programs. Prior to the acceptance and widespread use of EBDC fungicides the 10-year average yield of pepper was 65.8 cwt per acre. In the past 10 years, the yield has increased 18.8% to 78.2 cwt per acre.

Alternaria leaf spot and blight (Alternaria brassicae (Berkeley) Saccardo) and downy mildew (Peronospora parasitica (Persoon) Fries) are probably the most persistent and damaging of the cabbage diseases which are controlled by EBDC.

In 1976, 106,420 acres of cabbage for fresh market and processing were planted in the U. S. Maneb, maneb plus zinc and zineb are used extensively for the control of Alternaria leaf spot and downy mildew in the U. S. EBDC fungicides are a major part of all grower disease control programs on this crop. The 10 years prior to widespread acceptance and use of EBDC fungicides, cabbage yields averaged 156.6 cwt per acre. The next 10 years in which EBDC was used, yield rose 20.1% to 188.1 cwt per acre.

Downy mildew is a serious disease of lettuce. The EBDC fungicides, zineb and maneb, are used extensively for controlling this disease. Loss of these fungicides would result in crop losses of 15 25% as well as a quality (or grade) reduction of 40%.

Downy mildew and white rust are diseases of spinach which are controlled by EBDC fungicides. There are no effective registered alternatives.

Cucurbits are susceptible to a number of diseases that are effectively controlled by EBDC fungicides. Although alternatives are available, their increased cost would undoubtedly influence growers to reduce acreages.

Serious economic losses can occur in onion fields where protective fungicides have not been applied prior to conditions favorable for disease development. EBDC fungicides are used effectively for control of downy mildew, purple blotch and Botrytis leaf blight. Alternate fungicides vary with the disease and the area of the country.

The EBDC fungicide maneb has been recommended and used for the control of downy mildew of lima beans in the mid-Atlantic area for more than 20 years. It is the only safe effective compound available for this purpose. The lima bean industry could not exist in this area without the availability of maneb to control downy mildew outbreaks; the continued registration of maneb should and must be be maintained.

The EBDC fungicides are the only effective fungicides now available for the control of a number of diseases which can limit production of collards, eggplant, endive, escarole, kale, kohlrabi,

lentils, romaine, rutabaga, and Swiss chard. Economic production of these crops cannot continue without the availability of the EBDC fungicides.

Leaf spot diseases of peanuts must be controlled to prevent serious reductions in yields. A number of fungicidal compounds are being used to control these diseases. The EBDC fungicides are used on approximately 20% of the peanut acreage. The effectiveness of the current peanut disease control program would not be greatly diminished if the EBDC fungicides were no longer available. However, these fungicides have a long history of safety and proven performance and their use should be allowed to continue.

Potatoes

Fungicides are used to control the following major potato diseases in the U. S.: (1) seedpiece decay, (2) early blight, and (3) late blight. EBDC's, because of their extensive use history, efficacy, availability, and low cost, account for approximately 65% of all seedpiece treatment, 65% of all late blight treatment, and 60% of all early blight treatment in the U. S. This amounts to an estimated 6-7x10^6 lb active EBDC applied to an estimated 1,156,000 acres one or more times for foliar blight control and to 1,078,000 acres as seedpiece treatment. The viable alternatives are captafol and chlorothalonil as foliar blight sprays and captan as seedpiece treatment. Captafol and chlorothalonil are at least as effective

as EBDC's for early and late blight control but captan is not as effective as a seedpiece treatment. EBDC's are generally equivalent to all alternatives with respect to the following characteristics: (1) protectant efficacy, (2) lack of phytotoxicity, (3) lack of acute human toxicity, (4) absence of fungal resistance, and (5) broad spectrum activity. EBDC's are superior to all viable alternatives with respect to cost. The long use history with relative safety and continued efficacy, lower cost, and the fact that the harvested crop is not directly treated, combined with limited viable alternatives argue for maintaining EBDC registration for potatoes.

Mushrooms

Zineb is used as a fungicide on mushrooms to enhance both quantity and quality of production. The effect of its cancellation would be felt directly and immediately by growers through increased costs and lowered production and returns, and by consumers through higher prices and lower quality (particularly of fresh mushrooms). Magnitudes of these effects would depend upon regulatory decisions as well as upon production and marketing parameters that are not precisely known.

Because it is a fungus itself, the mushroom is particularly susceptible to fungal diseaes that thrive under the environmental conditions needed for optimum mushroom production.

The most severe of these diseases is Verticillium (dry bubble disease) for which zineb is the only effective defense. Zineb is also effective against other fungal pathogens such as Dactylium (mildew), Mycogone (wet bubble), and Trichoderma (green mold), as well as at least one viral infection (Lafrance disease).

There are no presently known alternatives to zineb in mushroom culture. At one time, benomyl was regarded as a very promising alternative but tolerance of Verticillium to benomyl developed very rapidly. Tolerance often has occurred at commercial mushroom farms in as little as 9 months or less of continued benomyl usage.

Use of environmental suppression by such methods as reduction of temperature and humidity are impractical because these environmental conditions are the very ones that are most crucial to favorable development of the mushroom.

Fruit

The EBDC fungicides maneb, mancozeb, metiram, and zineb are widely used on many tree fruits and small fruits because of the relatively inexpensive broad spectrum control.

The EBDC's are particularly beneficial for control of several major eastern apple diseases: bitter rot, black rot, white rot, and rusts. They are well adapted to integrated mite control program on apples because of their safety to predaceous insects and predaceous

mites and compatibility with most commonly used apple insecticides and other fungicides. Compatibility with benomyl and oil uniquely suits them for tank-mixing to reduce the threat of benomyl-resistant fungi, a characteristic which is particularly important in the northern apple growing regions. In the mid-Atlantic and lower mid-Western States, EBDC's are preferred particularly because of their utility in integrated pest management programs and long-term control of summer fruit rots. In the Southeast, EBDC's are the only fungicides that will adequately control the fruit rots prevalent under the warm humid growing conditions. Disadvantages of the major alternative apple fungicides which limit their adaptability to spray programs include: phytotoxicity to fruit or foliage, toxicity to predatory mites and predatory insects, incompatibility with other spray materials such as oils, fungal resistance, questionable availability, and uncertain registration situations.

Because of their broad spectrum economical control other important uses of EBDC's on fruits include: zineb on plums and prunes in the East for black knot disease, zineb and mancozeb on pears in the Northwest for pear psylla nymph control, zineb on hops in the Northwest for downy mildew control, mancozeb and maneb on grapes for control of fruit rots and downy mildew in several locations, zineb on oranges in Florida for greasy spot and fruit russet, and several EBDC's on minor acreage small fruits and home fruits and nuts.

Cereal Crops

The EBDC fungicides are used on the small grain (wheat, barley, and oat) crops as a seed treatment and as a foliar protectant.

The use of EBDC fungicides as seed treatment is not as effective as were the alkyl mercuries (no longer registered). The commercial seed treating equipment has had to be modified or new equipment purchased to apply the EBDC fungicides to small grains. At present the EBDC's are the most commonly used cereal treatments. Over a 10-year period average yields were increased by 4.1 bushels per acre.

For seedling disease, there is no way to establish an economic threshold until after the fact. Most of the seedling diseases are directly tied-up to the micro-environment occurring in the soil-seed association at this time of planting. Not to use seed treatment is to progress backwards.

The use of the EBDC fungicides as a foliage protectant against infection by *Septoria* spp., *Helminthosporium* spp. and the rust fungi is a world-wide practice. The practice and development of application techniques have been developed by myself and others in the early 1960's. Over a period of years cereal crop protection has averaged 28% yield increase over untreated crop. Unfortunately, there is no method for predicting the potential crop loss before it is too late to apply disease control practices.

The wildrice crop is extremely susceptible to several leaf-spot diseases that in most years are the limiting factor in crop production. The use of EBDC fungicides results in an increased cash return to the grower in excess of $400.00 per acre.

The practice of growing cereal grains, since the first observation of seed treatment effects, has utilized the concept of integrated pest management in the plant disease control area. Crop rotation, seed treatment, resistant varieties, foliar protection, and certified seed are all part of the integrated disease control program to produce the most crop per acre. The EBDC fungicides are a major tool in the cereal crop production program.

Ornamentals

Zineb is the EBDC most broadly registered and labeled for use by all segments of the ornamentals industry. Mancozeb is becoming more useful, as new research to add more uses to the ornamentals label progresses. The overall benefits of EBDC fungicides in ornamentals are their widespread usefulness on many diseases, the fact that they are not usually phytotoxic, they are readily available, and they are not expensive. Furthermore, the long use histories of these materials, significantly increase the confidence the ornamentalist has in using the materials on high value plants in sometimes unique growing or use situations.

Major EBDC benefits include control of the many rust diseases on woody and herbaceous ornamentals, prevention of anthracnose on shade trees, protection of chrysanthemums, gladiolus, and foliage plants from many diseases. There are a few EBDC uses on ornamentals for which there is no alternative material registered. However, the essentiality of EBDC uses on ornamentals is more clearly seen when one analyzes the disadvantages of the registered alternatives and adds this to those uses which have no alternative. Ornamentals require pesticides that give high levels of disease control because of the high value of the crops and the fact that any disease occurrence that detracts from the beauty of the plant can seriously lower market values of the crops. The same concept of detracting from beauty also comes to bear in evaluating alternatives that may leave residues or be phytotoxic to the plant in any way. Many of the EBDC alternatives are not as efficacious and are phytotoxic on many crops Finally, the oftentimes narrow spectrum or activity or existent labeling of EBDC alternatives limits their usefulness to a nurseryman, landscaper, greenhouse floriculturist, or homeowner, who may be attempting to protect many different plant types from many different diseases.

Grass Seed

The large majority of turfgrass and other seed production is concentrated in Washington and Oregon. It is estimated that 270,000 acres of grass seed production fields were maintained in Washington

and Oregon in 1977. Control of foliage, culm, and crown diseases is crucial to successful seed production. It is estimated that 50,000 acres of bluegrasses and ryegrasses for grass seed production were sprayed with the maneb and maneb plus nickel sulfate fungicides in 1977 for control of stem rust, strip rust, and leaf rust (*Puccinia sp.*).

The maneb materials are formulated as wettable powders. Two to four sprays per growing season may be applied depending on disease severity. These are applied at the rate of 1.6 to 2.4 lb. per acre of active ingredient in 50-100 gallons of water per acre.

In 1976 and 1977 in Washington and Oregon, grass seed yields ranged from 400-1000 lb. per acre where maneb treatments were applied. Without maneb seed yields were 100-300 lb. per acre (Dr. John R. Hardison); the rust diseases were primarily rsponsible for these losses.

Without the use of maneb the seed crop cannot be profitabily produced in areas with foliar disease problems.

Turfgrass

The importance of disease control in turfgrass culture has increased concurrently with the rising quality standards. Intense usage of these turf areas due to the leisure time recreation

explosion has necessitted comprehensive disease control practices which include fungicide treatment.

Maneb, mancozeb, and a lesser amount of zineb are among the major fungicides used throughout the U. S. for control of Helminthosporium pathogens. Smaller amounts are used for Rhizoctonia and Pythium diseases.

The maneb and mancozeb products are highly effective against the Helminthosporium diseases. They are the lowest cost fungicides available for the turf usage both in terms of price per pound as well as in price per unit area of turfgrass treated.

EBDC fungicide usage on turfgrasses will vary with the diseases to be controlled, the geographic location, and weather situation. Total number of EBDC applications in one growing season may range from one to ten. It is not possible to compute a meaningful average for either number of applications or dosages on a regional or nation wide basis.

Effective alternatives to the EBDC compounds are available and are used by turfgrass managers to varying extents depending on the material and diseases to be controlled. The alternatives are from 2 - 5 times more costly than the EBDC materials when used at equivalent rates to obtain similar levels of efficacy (Table 1).

At present chlorothalonil (Daconil 2787®), cycloheximide (Actidione®) and anilizine (Dyrene®) are the only three other fungicides with a high degree of activity against Helminthosporium. The loss of EBDC materials would accentuate potential fungicide resistance problems by increasing selection pressure for survival of strains resistant to the three alternatives.

Forestry

The forest industry does not consider it economically feasible to apply protectant fungicides to forest stands. The largest quantity of EBDC fungicide use on a forest product is nabam as a slimicide in the wet end of pulp and paper mills. Precise use figures ar not available. Total slimicide use (all fungicide) is around 4 million pounds.

In 1976 about 150,000 lbs of maneb were used to control needle cast of Christmas trees in 10,000 acres of plantings. A very small amount of maneb is used to control Herpobasidium blight of honeysuckle in windbreak plantings in the Plains States. Finally, about about 4,000 acres of tree seedling nurseries are treated annually with maneb to control needle casts, anthracnose, and leaf spot diseases. Since regeneration of the nations' forests depends upon nursery tree production, such a use is more important than may be realized with casual analysis.

INTRODUCTION

Definition of EBDC Fungicides

EBDC (ethylenebisdithiocarbamate) refers to a class of fungicides which includes nabam (Dithane D-14), maneb (Dithane M-22, Manzate), mancozeb (Dithane M-45, Manzate 200), zineb (Dithane Z-78) metiram (a mixture of Zinc NH^4 and ZnSDC) (Polyram), and diammonium EBDC (Amobam). Table 1 gives those names accepted for use in the ingredient statement on pesticide products as required by FIFRA regulations. Each is based on dithiocarbamic acid. They are used extensively in agriculture--on many fruits, vegetables, and field crops, turfgrass, seeds, and ornamentals--for the control of blights blotches, mildews, molds, rots, rusts, and other fungus--incited diseases. They have been in use for nearly 30 years. Domestic producers include DuPont, FMC, Pennwalt, Roberts Chemical, and Rohm and Haas. EBDC products are also manufactured in other countries and some are imported into the United States.

History of EBDC Fungicides

Up to the late 1930's, inorganic fungicides were the only materials widely available to the grower for the protection of agricultural crops from fungal diseases. Of these, Bordeaux mixture, a combination of copper sulfate and lime, was the most versatile. It

was widely used since its discovery in 1882 by Millardet in France. It replaced sulfur as a standard on many crops.

However, Bordeaux mixture suffered several problems. First, it was phytotoxic to the plants on which it was used at the effective application rates. It had a corrosive effect on the grower's spray equipment and frequently clogged nozzles. It was difficult to make up, because it entailed rather precise mixing of copper and lime in the spray tank. Finally, it left a heavy and noticeable residue on plant surfaces.

Aside from the copper compounds, the only other fungicides available in the early 1940's were lime-sulfur, sulfur dust and the wettable sulfurs which were used on fruit and vegetable crops for scab and crown rot and powdery mildews, and inorganic mercurial compounds which were used in the seed treatment of grain. Sulfur is still widely used today, especially to control powdery mildews.

Because of World War II, which placed a high priority on copper and mercury, there appeared a great demand for adequate substitute fungicides. The first derivative of a dithiocarbamate to achieve prominence was tetramethylthiuram disulfide, later called thiram. Next came the metal salts of dithiocarbamic acid.

The first reports of the metal salts of dithiocarbamic acid as successful field fungicides appeared in 1942 (Anderson, 1942;

Kincaid, 1942) when it was reported that ferric dimethyldithiocarbamate (ferbam) successfully controlled downy mildew on tobacco in seed beds. In comparison with the old recommendations of 12-16 lbs of sulfur per 100 gallons of spray, the use of ferbam at 1-1/2 lb per 100 gallons seemed strikingly effective, although it left an unsightly black residue on plant surfaces, its potential for crop injury was much less than that of the copper sprays or sulfur.

The promising control of early blight and anthracnose on tomatoes and early blight on potatoes achieved with zinc dimethyldithiocarbamate (ziram) was reported in 1944 (Heuberger and Wolfenbarger, 1944; Wilson, 1944).

Disodium ethylenebisdithiocarbamate (nabam) appeared in 1943 (Dimond, et al., 1943). Instability of nabam was a problem until the stabilizing effect of adding zinc sulfate to the spray tank was discovered. Its acceptance was rapid, and it became widely used for many vegetable diseases. The next step naturally followed - the manufacture of zinc ethylenebisdithiocarbamate itself, known as zineb. It became commercially available in the mid 1940's and was eventually developed for use on approximately 65 crops for 416 diseases.

In 1956, manganese ethylenebisdithiocarbamate (maneb) was field tested on potatoes and later on other vegetable crops. It became known as maneb. It was introduced commercially in the early 1960's. It was similar to zineb in its effectiveness as a fungicidal agent

on a number of crops, and better than zineb on many others. It is currently registered for use against 420 diseases on 72 crops.

In the early sixties a coordinated complex of the zinc and manganese salts of ethylenebisdithiocarbamate, named mancozeb, was introduced. It represented an even further improvement in the evolution of EBDC's, combining many of the benefits of zineb and maneb in one product. It is now labelled for use on 51 crops for 268 diseases.

General Qualities and Usefulness of EBDC's

In four years, from the time of its introduction in the mid 1940's, zineb replaced Bordeaux mixture as the standard fungicide on many crops in the United States. Within several more years the EBDC's had replaced Bordeaux, except in special situations, throughout the world. Such tremendous acceptance occurred because the EBDC's provided the growers for the first time with a good broad spectrum fungicide with no significant phytotoxic side effects. In addition, Powell and Shurtleff stated that the importance of this group of fungicides is emphasized by the fact that they controlled fungi that heretofore had not been effectively controlled by sulfur or copper compounds (1976). The rust diseases on fruits or ornamentals are good examples. Also, later chapters of this report will show that diseases caused by species of *Botrytis*, *Septoria*, *Alternaria* and anthracnose fungi were more adequately controlled.

For example, the production of potatoes, the most important vegetable in the world, has been increased dramatically since the introduction of EBDC fungicides. While it took the first 45 years of this century to increase the potato yield in the United States some 30% (from 91.8 bu/acre in the period 1901-1905 to 140.9 bu/acre in the period 1941-1945), potato yields increased almost 90% in the next nine years (to 208 bu/acre by 1954), (McNew, 1959). EBDC's along with the introduction of organic insecticides, improved spraying techniques, and new fertilizers had a hand in this increase.

Whereas all of these factors contributed to increased yields, EBDC's may well be the largest single factor. For instance, Heuberger and Manns (1943) reported in a test in Delaware with Dakota Red potatoes a 21% yield gain for nabam (Dithane D-14) plus $ZnSO_4$ plus lime, as compared with the use of Bordeaux mixture (the standard fungicide up to that time). Later on, Heuberger (1946) reported a 32% yield increase on potatoes grown in Delaware and treated with Dithane Z-78 (zineb).

Heuberger (1967) found in the mid 1940's that EBDC's gave control superior to copper compounds on tomatoes for all five of the common diseases -- the early blight, *Stemphylium* leaf spot, anthracnose, *Septoria* leaf spot, and late blight. The EBDC's also increased yields 2-3 tons per acre. Yield increases were also reported on cucurbits (25% or more) and celery. Yield increase

studies were also conducted by researchers on many crops including apples, corn, small grains, bananas, peanuts, and ornamentals.

There are no commercial fungicides which have as broad a target spectrum on as many crops as those in the EBDC class. There are substitutes for particular uses on particular commodities, but they are often less effective, more costly, or have more undesirable properties than the EBDC products.

EBDC's are compatible with most pesticides. This is important when incorporating them in total pest management--or integrated pest management--programs. For instance, in apple production the EBDC's are compatable with spray oils, and miticides, but are not toxic to the natural predators of the apple mite.

Finally, EBDC's are useful to combat the plant pathogens that are developing resistance to many of our more specific fungicides. As an example, the apple scab fungus has become resistant to other fungicides in many areas. As integrated pest management programs increase in use, the need for growers to use a general fungicide to quickly avert problems due to pathogen resistance will be ever more important.

Products Containing EBDC Fungicides

Our examination of current EPA microfische label files indicates that combined totals of all six EBDC materals amount to

271 crop registrations for 1,296 diseases, divided among 876 different products registered by 206 different companies (Table 2)! According to Farm Chemical Magazine (September, 1977) dithiocarbamate fungicides accounted for $50 million of a total $116 million U. S. fungicide market for 1974. Chemical and Engineering News of September 5, 1977, states that this market is growing by 7.3% per year. Thus, in 1977 the market would be about $61.75 million. Using this and other sales information, the assessment team estimates that at least 27 million pounds of EBDC fungicides are currently being used in this country each year. Recent compilations by several companies give yearly sales figures of 255 million pounds worldwide (out of a total of 460 million pounds of fungicides sold each year throughout the world).

The fact that so many registrants, so many products, and such widespread uses of EBDC's exist makes detailed analysis of EBDC uses impossible to analyze from the point of view of product distribution and sales. In an attempt to overview the registrant - product status, the assessment team wrote to each of the 209 registrants on the EPA registrant list that appeared with the RPAR in the Federal Register. Thirty-four percent of the 209 registrants responded with comments concerning 33% of the 865 products. Although this was not a great percentage of the total possible responses, a breakdown of the types of responses should help to illustrate and clarify the complex nature of EBDC registrations.

Over 50% of the responses (161 products) concerned products designed as foliar sprays on agricultural crops. The uses of these products were quite diverse, as is evident from the total registration picture mentioned above. Potato seedpiece treaters (primarily using dusts) represented 5% (or 13) of the product responses. Another 5% (or 14) were made up of products for water treatment in closed systems (pulp, sugar cane, cooling towers, etc.) for slimicide control.

Thirty-eight percent of the registrants responding were selling yard and garden products for use by homeowners. The numbers of such products represent 32% or 88 products. All of the registrants considered these products active in their product line, many stating that they were essential to the offering of a full service package. Very few registrants were able to cite alternative fungicides that they could substitute, although all did say an alternative would have to be sold. Sales information was offered by some registrants, but the data were too incomplete to benefit our analysis. It was clear from the responses that manufacturers of yard and garden pesticides would be seriously hurt by the removal of EBDC containing products. The fact that EBDC's are non-proprietary, inexpensive, compatible with other pesticides, broad spectrum, and of low phytoxic potential are quite important to this group of registrants.

WORLD USE OVERVIEW

Although the purpose of this report is to discuss EBDC fungicides with respect to their use in the United States, a brief discussion of world-wide use patterns is necessary for a complete analysis of benefits. Any restrictions placed on the EBDC fungicides in the United States may result in an unfair competitive advantage to U. S. producers on the world market. Export value to U. S. agricultural commodities is currently estimated at $23 billion annually, and does much to balance the expenditures for imported energy. Foreign producers will continue to use the EBDC fungicides, whereas U. S. producers may be forced to use more expensive alternatives. This would result in higher priced U. S. exports and a reduction in the volume of exports.

The estimated U. S. useage of the EBDC fungicides is between 25 - 27 lb. annually. World useage is estimated at 255 million lb. (Table 3). With the exception of large useage on foreign grapes for downy mildew control, and for bananas for Sigatoka disease control, world useage patterns on vegetables and other fruits closely follow those in the United States.

World production of bananas for 1975 was 6,641 thousand metric tons (FAO, Trade Yearbook, 1975). EBDC products are used throughout the major banana producing ares of the world to control Sigatoka and other diseases. Rigid residue standards on imported bananas by the

United States could influence imports. Realizing that the portion of bananas imported into the United States is a fraction of total produced, it is unrealistic to expect other nations to use alternative types of fungicides which do not provide the same broad spectrum of control as EBDC's and which cost more. The same case can be stated for other crops of which U. S. purchases are relatively small.

During 1973/74 about 50% of the total U. S. utilization of fresh tomatoes were imported from Mexico (Simmons, et al., 1976). Mexico and Florida growing conditions and costs of production are similar. Since EBDC's are more economical to use, it is reasonable to assume that Mexico will continue to take advantage of availability of EBDC's and thus further increase its cost advantages. The same situation might occur concerning bell peppers and cucumbers for which imports from Mexico account for 36% and 46%, respectively, of the U. S. market.

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Table 1. EBDC Nomenclature
(Source: EPA Position Document 1 on Ethylenebisdithiocarbamates)

Common Name	Label Chemical Name	Trade Name(s)	CAS Name	CAS Number
1. None	Diammonium EBDC	Amobam®	Carbamodithioic acid, (1,2-ethanediylbis-, diammonium salt	3566-10-7
2. Mancozeb*	**	Dithane® M-45 Manzate® 200	[[1,2-Ethanediylbis [carbamodithioato]] (2-)]manganese mixture with [[1,2-ethanediylbis [carbamodithioato]] (2-)]zinc	8018-01-7
3. Maneb	Manganese EBDC	Manzate® Dithane® M-22	[[1,2-Ethanediylbis [carbamodithioate] (2-)]manganese	12427-38-2
4. Nabam	Disodium EBDC	Parzate® Dithane® D-14	Disodium 1,2-ethane-diylbis[carbamodithioate]	142-59-6
5. Metiram*	***	Polyram®	Metiram	9006-42-2
6. Zineb	Zinc EBDC	Dithane® Z-78	[[1,2-Ethanediylbis [carbamodithioato]] (2-)]zinc	12122-67-7

* Recognized in Europe but not yet established in the United States. These names will be used in this document for convenience.

** Zinc ion and manganese ethylene bisdithiocarbamate 80%, a coordination product of manganese 16%, zinc 2%, ethylene bisdithiocarbamate 62%.

*** Mixture of 5.2 parts by weight (89.9%) of ammoniates of [ethylenebis(dithiocarbamate)]zinc with 1 part by weight (16.1%) ethylenebis[dithiocarbamic acid], bimolecular and trimolecular cyclic anhydrosulfides and disulfides.

Table 2. Total registrations and product summary for EBDC fungicides.

Chemical	Crop Registrations	Number of Diseases	Number of Products*
Diammonium EBDC	21	47	2
Nabam	44	104	51
Mancozeb	51	268	110
Maneb	72	420	306
Zineb	65	416	354
Metirm	18	41	53
Totals	271	1296	876

*Number of separately labelled properietary formulations, including those containing EBDC's alone or in combination with other pesticides. Taken from EPA label microfische files.

Table 3. Estimated world uses of EBDC fungicides in 1975*

Crops	Millions of Pounds
Plantation Crops	4.410
Bananas	9.875
Fruits and Nuts	27.344
Rice	3.518
Major Field Crops	10.713
Vegetables	35.692
Potatoes	60.463
Tomatoes	19.267
Seed Treatment	3.509
Turf and Ornamentals	0.650
Vineyards	79.996
Total All Uses	255.320

*Based on assessment team compilations and sales estimates by Rohm and Haas Chemical Company.

Vegetables

Vegetables are grown in every state of the Union. In 1976 there were 3.2 million acres of vegetables (exclusive of potatoes) planted. It is estimated that the same acreage will be planted in 1977 and that there will be an estimated 10,000,000 lb. of EBDC fungicides used. Approximately 8,000,000 lb. will be usedrs as well as commercial growers. Approximately 8,000,000 pounds will be used east of Mississippi with at least half of it to be used in Florida alone. Approximately 2,000,000 lb. will be used west of Mississippi with 1/4 of it used in California vegetable production. These fungicides are used extensively by home gardeners as well as commercial growers, but precise areas of need and total use figures are not available.

The EBDC fungicides are used to control most of the major foliar pathogens of vegetables in the United States. The total economic importance of vegetable diseases must be measured not only by the actual damage that they cause but also by the cost of disease control. It is next to impossible to accurately calculate the dollar cost that diseases impose upon vegetable industry. Data show that maneb, maneb plus zinc, and mancozeb are generally superior to most labeled alternates on the major diseases of vegetables. The only alternatives, for the most part, that are outstanding for some major vegetable diseases, are chlorothalonil and captafol (Table 1).

Sweet Corn

The most serious diseases of sweet corn which are controlled with EBDC's in the U. S. are northern leaf blight, caused by *Helminthosporium turcicum* Passerini, southern leaf blight caused by *Helminthosporium maydis* Nisik and Miyake, and corn rust caused by *Puccinia sorghi* Schweinitz (19, 20, 21).

In 1976, 183,100 acres of sweet corn were planted in the United States and treated with EBDC fungicides. In Florida, 973,000 pounds were used extensively for control of leaf blight and corn rust (Table 2). Zineb, metiram, captafol, and chlorothalonil are registered on sweet corn but are not used because of the higher program cost (Table 2). Applications of EBDC fungicides to sweet corn consist of an average of 11 treatments per crop applied at the rate of 1.2 lbs. a.i./acre/treatment.

Snap Beans

Bean anthracnose [*Colletotrichum lindemuthianum* (Saccardo and Magnus) Scribner] and bean rust (*Uromyces phaseoli typica* Arthur) are serious diseases of snap beans which are controlled with EBDC fungicides. Ahthracnose is almost worldwide in distribution. However, it is rarely found in the dry-land or surface-irrigated seed areas of the western United States. Bean rust is found in every country and state where beans are grown intensively (27).

In 1976, 339,000 acres of snap beans were planted in the U. S. In Florida, 38,900 acres were planted, and 37,500 acres were treated with EBDC fungicides. There are 457,500 pounds of EBDC fungicides used on this crop annually. EBDC fungicides are a major component of disease control programs on snap beans. During the 10 years prior to widespread use of EBDC fungicides on snap beans, and average yield was 29.0 cwt/acre. After 10 years with EBDC fungicide use, the yield rose 10.7% to 32.1 cwt/acre. Other changing production practices have contributed to yield increases, but EBDC fungicide use appears to be the primary cultural practice resulting in these increased yields.

Maneb, maneb plus zinc are used extensively for control of anthracnose and bean rust on snap beans. Chlorothalonil is the only alternative useful for bean rust control. Zineb is labeled for anthracnose bean rust, but is no longer widely used. Applications of maneb, and maneb plus zinc fungicides to snap beans average 5.8 treatments per crop applied at the rate of 1.2 lb. a.i./acre/-treatment at the program cost of $13.27/acre. Zineb treatment also averages 5.8 applications per crop applied at the rate of 1.5 lb. a.i./acre/treatment at a progrm cost of $16.59/acre. Chlorothalonil for rust control is applied just as frequently at the rate of 2.25 lb. a.i./acre/treatment at a program cost of $60.90/acre.

Celery

Early blight and late blight are the most serious diseases of celery which are controlled with EBDC fungicides.

Early blight, caused by Cercospira apii, is known to occur in every country where celery is grown intensively (71). Late blight of celery caused by Septoria apii and Septoria apiigraveolentis is a devastating disease found in all celery production areas of the world (15). Early infection by these two fungi destroys the entire crop long before harvest time. Septoria predisposes the celery stalks to Aclerotinia while in storage. This disease destroys the stalks before they can be marketed.

In 1976, 34,910 acres of celery were planted in the United States. In Florida, 10,900 acres were planted and all were treated with EBDC fungicides. Maneb, maneb plus zinc, and mancozeb are used extensively for the control of celery early blight and late blight. Zineb, metiram, benomyl, chlorothalonil, copper, ferbam, thiram, and dichlone are all labeled for control of these disease (Table 3). Use of EBDC fungicides on celery in Florida consists of an average of 20.2 applications per crop applied at the rate of 1.2 lb. a.i./acre/treatment. Florida uses 314,000 lb. of EBDC fungicides annually; 96.5% of all celery growers in Florida use EBDC's in disease control programs. During the 10 years prior to widespread use of EBDC on celery, yields averaged 295 cwt/acre. They rose to 388.4 cwt/acre during the following 10 years, due in large part to the use of these more effective fungicides. In California, 20,050 acres of celery were planted and 4,010 acres were treated with EBDC. Applications of EBDC to celery in California consisted of 7 treatments per crop at the rate of 1.2 lb. a.i./acre/treatment.

Peppers

Phytophthora blight, frogeye spot, and anthracnose are diseases on peppers having varying degrees of importance throughout the United States. All three disorders are generally controlled with EBDC fungicides. Phytophthora blight caused by Phytophthora capsici is found in many of the pepper production areas of the world (44, 63, 69, 70). Frogeye spot caused by Cercospora capsici is the most common leaf spot on peppers (12, 69). It is found throughout most of the pepper production areas in the world. When the disease is severe, it can produce almost complete defoliation of an entire field. Anthracnose caused by Gloesporium piperatum is found in many of the pepper production areas. Overhead irrigation greatly increases the severity of the disease by prolonging the period of favorable humidity and washing off of the protective fungicides.

In 1976, 57,000 acres of peppers for fresh market and processing were planted in the United States. In Florida, 17,600 acres were planted and 12,200 acres (60%) were treated with EBDC fungicides. Maneb, maneb plus zinc, and zineb are used extensively for the control of frogeye spot, and anthracnose. Phytophthora blight is also controlled in this spray program. Some copper fungicides are the only alternative and it is only recommended for frogeye spot (Table 4). Applications of EBDC fungicides to pepper average 7.6 treatments/crop. Maneb or maneb plus zinc is applied at the rate of 1.2 lb. a.i. Zineb is applied at the rate of 1.5 lb. a.i./acre/ treatment. In Florida, 214,400 lb. of EBDC fungicides are used

annually on peppers. The EBDC fungicides are a major part of most pepper disease control programs. Prior to the acceptance and widespread use of EBDC fungicides, the 10-year average yield of pepper was 65.8 cwt/acre. In the past 10 years, the yield has increased 18.8% to 88.2 cwt/acre. It is generally recognized that a great deal of this yield increase was due to the use of the more efficacious EBDC materials.

Cabbage

Alternaria leaf spot and blight caused by *Alternaria brassicae* (Berkeley) Saccardo and downy mildew caused by *Pernospora parasitica* (Persoon) Fries are probably the most persistent and damaging of the cabbage diseases which are controlled by EBDC. Alternaria leaf spot and blight is almost worldwide. Infected seedlings used as transplants never grow as large as normal nor do they yield well. If infection is delayed until plants are older, the spots usually occur on the older leaves and are not generally economically important unless the spotting is severe enough to require extensive trimming as the cabbage is placed in storage. Downy mildew is especially common in California. Its severity varies from year to year depending upon weather conditions.

In 1976, 106,420 acres of cabbage for fresh market and processing were planted in the United States. In 1976, 18,100 acres were planted in Florida and 16,670 (92%) treated with EBDC fungicides. California planted 7,700 acres and 3,080 were treated with EBDC

fungicides. Maneb, maneb plus zinc, and zineb are used extensively for the control of Alternaria leaf spot and downy mildew in the United States. In Florida 121,500 lb. of EBDC fungicides are used on cabbage annually. EBDC fungicides are a major part of the disease control programs in Florida on this crop (Table 5). Use of EBDC on cabbage in Florida consists of an average of 4.9 applications/crop applied at the rate of 1.2 lb. a.i. for maneb, maneb plus zinc, and 1.5 lb. a.i. of zineb/acre/treatment.

Fresh Tomatoes

Fungicidal sprays are used to control four major foliar pathogens of tomatoes: *Alternaria solani* (Ellis and G. Martin), Jones and Grout, *Cladosporium fulvum* Cooke, *Stemphylium solani* Weber, and *Phytophthora infestans* (Mont) deBary. Foliar sprays are used to control one or more of these pathogens which attacks tomatoes in the 12 major tomato production states.

Early blight caused by *A. solani* can be a devastating disease which is present in almost all states and countries where tomatoes, eggplant, and potatoes are grown (53). It reaches epidemic proportions in areas with high rainfall with temperatures in the range of 75° to 85° F (49). Tomatoes are sprayed regularly in most production states, begining at plant emergence of direct seeded fields or soon after plant establishment of transplants. In California, early blight is a problem in fields with overhead irrigation or when unseasonal rains are encountered, such as occurred in

early 1978. Most of the commonly used fungicides, such as mancozeb, maneb, maneb plus zinc, zineb, ziram, metiram, captan, captafol, folpet, chlorothalonil, and anilazine can be applied for early blight control. The large number of chemicals is desirable because the tomato spray schedules in most tomato production areas are always built on the assumption that anthracnose, late blight, and leaf mold may be present and, thus, broad spectrum crop protection is necessary. Maneb, maneb plus zinc, and mancozeb control all three of these diseases, unlike many of the alternative materials occasionally used in the spray program.

Tomato late blight caused by P. infestans (Mont) deBary is one of the most widespread plant diseases known to man. This pathogen can bring quick devastation to a tomato crop (9). Infected fruits are invaded by secondary fungi and soft-rot bacteria resulting in fruit disintegration. In some tomato production areas fungicide sprays are not necessary to protect the crop from late blight for the entire season depending on the temperature, moisture, and presence of the fungus. Thus, a forecast system is utilized and disease control costs are reduced (16, 30). As was the case for early blight, maneb, maneb plus zinc, and mancozeb are the foremost fungicides used for control of late blight.

Leaf mold of tomato (caused by Cladosporium fulvum) is world-wide and causes a great deal of injury to winter grown crops in greenhouses. In Ohio, 40 percent of the greenhouse acreage is sprayed 2 to 3 times with EBDC's for control of leaf mold. In

fields protection is needed during wet, moderately cool seasons (7). Chemicals which have been proven effective in disease control in the field are maneb, maneb plus zinc, mancozeb, zineb, benomyl, captan, and chlorothalonil. The only alternative chemical in greenhouses is benomyl.

Grey leaf spot was found first in Florida with a northern range to Indiana and Illinois (26). It is a serious problem in Hawaii and Central America. The fungus may be found on seedlings as well as mature plants. Varying degrees of severity can occur from a single leaf spot to complete defoliation of the plant. The fungus is favored by hot, wet weather and having the plants weakened by a heavy fruit load or fertilizer--depleted soil. The effective chemicals for disease control are maneb, maneb plus zinc, mancozeb, zineb, ziram, metiram, captan, captafol, chlorothalonil, and anilazine.

In 1976, 11 states planted 109,800 acres of fresh market tomatoes and 72,305 were treated with EBDC fungicides (Table 6). The number of applications of EBDC to a crop of fresh tomatoes ranged from 4 in California and Georgia to 22 in Florida (Table 7). The rate of EBDC active ingredient applied ranged from a low of 1.2 lb./acre/treatment in North Carolina to a high of 2.4 lb./acre/treatment in Maryland, Virginia, and New York (Table 7). Without the use of EBDC fungicides, crop reductions of 10-20% in California and 20-30% in 9 other states (Table 8) might be expected. It is estimated that the industry could have losses in yield ranging from

46 to 118 cwt/acre, if EBDC fungicides were not available and the on substitutes were the copper compounds. Common formulations and costs of formulation of EBDC fungicides and registered alternatives on tomatoes are listed in Table 9. The main objection to the use of equally efficacious alternatives is the higher costs of these materials.

Processed Tomatoes

In 1976, approximately 332,500 acres of tomatoes were grown for processing alone (65). About 80% of this acreage was centered in California while most of the remainder was located in Ohio, Indiana, Michigan, New Jersey, Maryland, and Pennsylvania (Table 10). The yield and quality of processing tomatoes are often seriously reduced by a number of fruit and foliar diseases. Early blight caused by *Alternaria solani*, and anthracnose caused by *Colletotrichum phomoides* occur most commonly and account for the major portion of the damage. On occasion, late blight caused by *Phytophthora infestans* may develop in areas of cool temperatures and cause considerable destruction of acreage. At times, Septoria blight caused by *Septoria lycopersici* and gray leaf spot caused by *Stemphylium solani* cause considerable foliar damage. In addition, black mold caused by *Alternaria alternata*, and *Botrytis* mold caused by *Botrytis cinerea* can also reduce yields. The damaging effect of all these diseases can be nullified to a large extent by an efficient disease control program. The EBDC fungicides have played an important role in this

program for processing tomatoes for more than 25 years. At the present time, maneb, and mancozeb are the most widely used EBDC fungicides for tomato disease control in the Eastern United States (Tables 11, 13).

The available alternatives for the control of various diseases of processing tomatoes are listed in Table 12. Although this list is extensive, captafol (Difolatan) and chlorothalonil (Bravo) are the most frequently used compounds of all the alternative fungicides, with chlorothalonil being the preferred of these two. Considerable field research has been undertaken to compare the efficacy of maneb, captafol, chlorothalonil, and other compounds for tomato disease control (6, 10, 23, 33, 41, 43, 60). A summary of data obtained in 10 experiments is presented in Table 14. These results indicate that captafol and chlorothalonil are slightly more effective than maneb in controlling anthracnose and early blight. Other workers have reported similar findings (22, 45, 51, 58, 61).

One of the big advantages of the EBDC fungicides has been their relatively inocuous effect on the tomato plant. Chlorothalonil and captafol are also noninjurious to tomatoes. However, captafol has certain properties that can be irritating to perons coming in direct contact with this compound. This would readily occur during hand-harvesting. Therefore, the use of captafol is restricted to tomatoes which are mechaniclly harvested. Captafol is more widely used in California because practically all the tomatoes there are

mechanically harvested. In the East, the majority of the acreage is still handharvested. Chlorothalonil does not exhibit any phytotoxic properties and only occasionally have reports indicating worker irritations been received.

The costs per acre of one application of captafol, chlorothalonil, and EBDC fungicides (maneb or mancozeb) are $5.00, $8.93, and $4.56, respectively. Using captafol would increase slightly the cost of a tomato disease control program; however, one must remember that this compound is restricted to mechanically-harvested tomatoes. Since the majority of tomato acreage in the Eastern United States is hand-picked, the only other possible alternative fungicide would be chlorothalonil. Changing from EBDC fungicides to chlorothalonil would almost double the cost of an effective tomato disese control program. With eight fungicidal applications made during the season, the increase in cost per acre would be at least $35.00 to achieve the same level of disease control.

In general, the loss of EBDC's on tomatoes would result in the availability of only one effective compound which could be used for hand-picked tomatoes. Irrespective of the increased costs which would occur with the loss of EBDC fungicides, it would be unwise to rely on just one fungicide for the control of foliar and fruit diseases. In the future, there will be new cultivars and changing cultural practices. These changes might result in introduction of new tomato pathogens, and possible development of resistance by

current pathogens. All these factors require some latitude in choice of fungicides.

Lima Beans

Lima beans are an important vegetable commodity in the Mid-Atlantic area. The lima bean acreage is primarily located in New Jersey, Maryland, and Delaware with a total of approximately 15,000 acres planted and harvested during the 1977 season (65). These lima beans are commonly referred to as "baby limas" and are used exclusively for processed beans (canned or frozen). This baby lima acreage represents a large part of the total production of this crop in the United States.

Downy mildew (*Phytophthora phaseoli*) has been a problem of lima beans in the Mid-Atlantic area since the early 1900's (13). The environmental temperture and moisture here are well suited for the development and spread of this disease. Hueberger and Crossan in 1958 (18) reported losses of approximately $200,000 to growers in Delaware from downy mildew infection of lima beans where protective fungicidal sprays were not used. These workers further reported that 13 years of research with copper and organic fungicides showed that maneb was the most effective fungicide for downy mildew control of lima bens. The results obtained in several downy mildew control tests in Delaware (18) are summarized in Table 15. These results showed that the maneb compound was effective in controlling downy mildew and an increase in bean yield was obtained. Downy mildew

outbreaks in the mid-Atlantic area occurred 5 times during the last 10 years (1968-77). Approximately 60% of the lima bean acreage was treated with an EBDC fungicide during these outbreaks. Growers used an average of 4 applications (7-day schedule) at eht rate of 1.6 lb. a.i./acre/application.

Copper is the only alternative compound for the control of downy mildew of lima beans. However, it is recommended as an alternative to maneb on only two states. Fifteen states including Delaware, Maryland, and New Jersey do not recommend any alternative compound for downy mildew control of lima beans because of the lower efficacy and phytotoxicity hazards associated with the use of coppers. No phytotoxic effects were observed when maneb sprays were applied to lima beans for downy mildew control in fields tested in Delawre (18). Studies conducted by the Department of Plant Pathology, Rutgers University (8), indicated that copper sprays were injurious to lima beans. In these studies the yields of the copper-sprayed lima bean cultivar Henderson were reduced 27 to 54 percent as compared to the untreated plants. It is apparent that maneb is the <u>only</u> acceptable fungicide now available for downy mildew control of lima beans.

A method has been developed by Hyre (31) for forecasting downy mildew of lima beans in the mid-Atlantic area from rainfall and temperature data. Therefore, lima beans do not have to be sprayed on a regular schedule for control of this disease. Another important

downy mildew control measure used during the last 15 years has been the use of resistant varieties (73). Unfortunately, the mildew pathogen has developed a new race with each new resistant cultivar introduced.

Peanuts

Peanuts are an important crop in the United States, particularly in the South. The leaf spots (*Cercospora personata* and *Cercosporidum arachidas*) are probably the most serious diseases of peanuts in the United States (32). During the years 1951 to 1960, the average annual loss from these diseases, despite the use of chemical control measures, was estimated at 10 percent (64). A recent report from Wells (72) showed that there was an estimated loss of yield of approximate 8 percent from these leafspot diseases in the major peanut-growing states during the 1975 and 1976 seasons. These losses continue to occur and could exceed 50 percent if chemical control measures were not utilized.

A number of compounds, in addition to the EBDC fungicides, are used to control these diseases of peanuts. These alternative fungicides are: benomly, chlorothalonil, captafol, dodine, triphenyltin, copper, and sulfur. The EBDC fungicides (maneb and mancozeb) are being used extensively in North Carolina, Oklahoma, Texas, and Virginia. During 1977, approximately three million pounds were applied to about 275,000 acres of peanuts in these states representing 20 percent of the total peanut acreage in the United

States (8, 29, 50, 68, 72). Usually, there are 6 applictions at a rate of 1.4 lb. a.i./acre/treatment.

The most widely used alternative compounds are chlorothalonil (Bravo), copper (Kocide), captafol (Difolatan), and triphentin (Duter). Gazaway (24) has reported that these compounds were effective for foliar disease control in tests in Alabama. Chlorothalonil would be the preferred alternative and would be applied 5 times at a rate of 1.3 pts/acre/treatment. Benomyl (Benlate) use is limited because of pathogen resistance. Maneb or mancozeb must be used in combination with benomyl to conteract this problem.

Since many alternative fungicidal compounds can and are being used, a cursory view that the loss of EBDC fungicides would not have an immediate economic impact on the peanut industry (24, 56, 62). The cost of these materials in a disease control program is comparable to the EBDC fungicides. However, over the long run, the effect of the loss of EBDC fungicides could prove to be substantial. Their loss would mean that there would be one less effective fungicide to recommend in a "rotation" program. Horne (29) at Texas A&M recommends that peanut growers use different fungicides within a spray program to avoid the possibility of building up tolerant or resistant strains of the pathogens. He further states that the EBDC fungicides have been used for many years without any loss in effectiveness or any adverse affect upon the peanut crop or environment.

Lettuce

Downy mildew (Bremia lactucae) is a serious disease of lettuce which occurs in all parts of the world where there is adequate moisture and medium to low temperatures. In wet weather the affected leaves often are rotted by saprophytic bacteria or fungi.

In 1976, 155,100 acres of lettuce were planted in California and 38,775 treated with EBDC fungicides. Zineb and maneb are used extensively for the control of lettuce downy mildew. Materials such as chlorothalonil (Bravo), captafol (Difolatan), Dyrene, etc., are not registered for use on lettuce. Applications of EBDC to lettuce consisted of 2.5 applications per crop applied at the rate 1.6 lb. active ingredient per acre per treatment. Without the use of the EBDC fungicides, growers would have suffered a 15-25% loss in yield. Bordeaux mixture, 6:6:100, is an excellent protective fungicide, but it caused injury to plants (14). Liquid copper materials may cause yellowing of wrapper leaves and light brown necrotic areas on leaf and leaf blades with repeated applications (48). It is estimated we could have a 15-25% reduction in grade and quality resulting in a loss to the producer of approximately $1.00/carton if EBDC fungicides were not available and the only substitutes were the copper compounds. In 1976, 37,300 acres of lettuce were planted in Arizona and 18,650 (50%) were treated with EBDC fungicides. Applications and loss estimates were similar to those in California.

Because of the high humidity and ideal conditions for development of downy mildew in Florida, it is necessary to treat 100% of the acreage whenever lettuce is grown. In 1976, 9400 acres of lettuce were planted. Growers usually use 2 applications per crop at the rate of 1.6 lb. a.i./acre/treatment. The cost of the fungicide in Florida varies from $4.58 to $5.72 per acre. Yield loss and quality grade reductions without EBDC treatments would be roughly the same as that incurred in California and Arizona. No effective alternate fungicides are available for the control of downy mildew of lettuce. Downy mildew strains of the fungus have never developed resistance to the EBDC fungicides. There are no reports of EBDC fungicides causing irritation to humans who have handled the fungicides constantly in the field or by harvesting the treated plants.

Spinach

Downy mildew of spinach (*Peronospora spinaciae*) is another disease for which EBDC fungicides are needed for control. As far as is known, no effective alternates are available. In severe attacks the entire plant is killed. The disease progresses so rapidly that within a few days the entire field may be destroyed. Resistant varieties are available, but the fungus has the ability to produce new strains which can attack resistant varieties.

In 1976, 3500 acres of spinach were planted in Texas, and 100% of the acreage was treated for either control of downy mildew or

white rust (Albugo occidentalis). Zineb or maneb are the EBDC fungicides used most often for control of spinach diseases and 4.5 treatments are applied per crop at the rate of 1.6 lb. a.i./acre/treatment. Without the EBDC treatments growers would lose 100% of their planted acreage during periods of high disease incidence.

In 1976, 3280 acres of spinach were planted in the mid-Atlantic States of New Jersey, Maryland, and Virginia, and 2200 acres (65%) were treated with EBDC fungicides. The average number of treatments per crop was 4.5 and 1.6 lb. a.i. of the fungicides were applied/acre/treatment. It is important to restate that there appear to be no alternate fungicides for the control of downy mildew or white rust of spinach. Growers must have the EBDC fungicides for control of these two diseases, if they are to continue growing spinach.

Cucurbits

Major diseases of the cucurbit family (watermelon, squash, cucumbers, cantaloupes, calabaza, etc.) include downy mildew caused by Pseudoperonospora cubensis, gummy stem blight caused by Mydosphaerella citrullina, and target spot caused by Corynespora cucumerinum. EBDC is used to control the downy mildew fungus on calabaza, which becomes a problem during the fall months, the major production period. Without adequate EBDC preventive sprays, foliage damage occurs resulting in fruit size reduction and number (2, 3, 4,

28, 54, 55, 59). Downy mildew of cantaloupe can be a serious disease in Texas and the desart valleys of California during the fall cropping period.

In 1976, 65,000 acres of watermelons were planted in Florida and 49,200 acres were treated for cucurbit diseases. Six and one-half applications of EBDC fungicides were used per crop at the rate of 1.6 lb. a.i./acre and approximately 412,560 lb. were used during the season; 39,000 acres of watermelons were planted in Georgia and 26,500 acres were treated with EBDC fungicides. Six application of fungicide were applied during the crop season at the rate of 1.6 lb. a.i./acre/treatment; 25,000 acres were planted in South Carolina and 20,000 acres were treated with EBDC fungicides. Five applications of EBDC fungicides were used per crop at the rate of 1.2 to 1.6 lb. a.i./acre/treatment; 35,000 acres of watermelon were planted in Texas and 29,000 acres were treated with EBDC fungicides/acre/application. In Alabama, 15,000 acres were planted and 2000 acres were treated with EBDC fungicides, while in Mississippi, 14,000 acres were planted and 4000 acres were treated. Five to seven applications of EBDC fungicides were used during the crop season and 2.0 lb. a.i./acre/treatment. In general, chlorothalonil would serve as an alternative fungicide on watermelons. Its use is not widespread now because of the considerably higher cost of chlorothalonil.

In 1976, 15,500 acres of cucumbers for fresh market were planted in Florida and 12,800 acres were treated with EBDC fungicides. A total of 96,300 lb. of fungicide were used during the season on cucumbers. The dosage used/acre/application was 1.4 to 1.6 lb. a.i. and usually consisted of an average of 6.8 applications during the crop season. The cost per acre of fungicide was $18.15. Chlorothalonil is the preferred alternative fungicide and would be used at a cost of $59.50 per acre. In North Carolina 8800 acres of fresh cucumbers were planted and 1760 acres were treated with EBDC fungicide (4 applications at a rate of 1.6 lb./acre/treatment.) South Carolina planted 5900 acres and the entire acreage was treated with EBDC fungicidies. Growers applied an average of 4.5 applications per crop season at the rate of 1.4 lb. a.i./ acre/treatment. In Michign 2000 acres were planted and 1200 acres were treated with EBDC fungicides. Six applications were used during the crop season at the rate of 1.4 lb. a.i./acre/treatment. Chlorothalonil would be the preferred alternative (4 applications at a range of 1.88 lb. a.i./acre/treatment).

EBDC fungicides are important in Michigan, North Carolina, and South Carolina for controlling various diseases attacking processing cucumbers (pickles). Gummy stem blight, downy mildew, Alternaria leaf spots, and scab would be the principal diseases to be controlled. In 1976, 27,000 acres of processing cucumbers were planted in Michigan and 16,000 were treated with EBDC fungicides. Growers used an average of 4.5 applications per crop at the rate of 1.2 lb. a.i./acre/treatment. In North Carolina 28,000 acres were planted

per crop at the rate of 1.2 lb. a.i./acre/treatment. In South Carolina 7900 acres were planted and 100% of this acreage was treated for disease control. Growers used 4.5 applications per crop at the rate of 1.4 lb. a.i./acre/treatment.

Chlorothalonil would be the preferred fungicide for control of diseases in processing cucumbers and would usually consist of 4.5 applications per crop at the rate of 1.6 to 1.8 lb. a.i./acre/-treatment. As in other crops, the chlorothalonil treatment would be more expensive than the currently used EBDC fungicides.

Downy mildew of cantaloupe can cause serious losses to occur in the production areas of Texas where 17,000 acres were planted in 1976 and 75% of this acreage was treated with EBDC fungicides. Average number of applications per crop season was 4.5 to 2.0 lb. a.i./acre/treatment. Both cholorothalonil and captafol would be the alternatives for control of cantaloupe downy mildew. Chlorothalonil would be used at 2.25 lb. a.i., while captafol would be used at 2 lb. a.i./acre/treatment.

<u>Onions</u>

Serious economic losses can occur in onion fields where protective fungicides have not been applied prior to conditions favorable for disease development. Diseases involved include downy mildew

caused by Peronospora destructor, purple blotch caused by Alternaria porri and Botrytis leaf blight (1, 5).

In 1976, 32,000 acres of onions were planted in Texas; 24,000 acres were treated with EBDC fungicides. In New York 14,300 acres were planted of which 9,000 were treated. Growers used an average of 6 applications of EBDC fungicides per crop and 2.4 lb. a.i./acre/treatment; 7300 acres of onions were planted in Michigan and 4700 were treated with EBDC fungicides. Growers used an average of 8 applications per crop at the rate of 1.2 lb. a.i./acre/-application. In California 6400 acres were planted in 1976 and 2880 acres were treated. Growers used an average of 3.5 applications per crop at the rate of 2.4 lb. a.i./acre/application.

Alternate fungicides for onions would vary with the disease and the area of the country. For purple blotch control in California, growers would use anilazine. New York, Texas, and Michigan with Botrytis leaf spot problems would use chlorothalonil as the alternate material (4 applications; 1.13 lb. a.i./acre/treatment). Captafol has been recommended for control of powdery mildew of onions and has been used at the rate of 2 lb. a.i./acre/application, but in some tests good control has not been achieved. Benomyl is another possibility for Botrytis control, but is also on the RPAR list. Benomyl tolerant isolates of Botrytis have developed on several other coprs with repeated applications.

Other Vegetable Crops

There are a number of "specialty" vegetables which have rather limited acreage. These include asparagus, collards, eggplant, endive, escarole, kale, kohlrabi, lentils, romaine, rutabaga, and Swiss chard. Despite their relatively small acreage, they are economically important to many growers involved in their production. The EBDC fungicides play a vital role in the control of diseases of these crops (Tables 1 and 16). It is important to note that at this time, the EBDC fungicides are the only effective fungicides available for the control of many of these diseases.

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TABLE 1. EBDC Fungicides and Alternative Fungicides Registered for Control Diseases of Vegetables*

Plant	Disease	Registered EBDC	Alternative** Fungicide
Asparagus	Crown rot	mancozeb	captan
	Rust	mancozeb maneb Polyram zineb	sulfur
Beans (field and snap)	Angular leaf spot	zineb	none available
	Anthracnose	maneb zineb	none available
	Downy mildew	maneb zineb	copper
Powdery mildew	maneb	sulfur	
	Rust	maneb zineb	chlorothalonil sulfur
Beans (lima)	Anthracnose	maneb zineb	none available
	Downy mildew	maneb	copper
	Rust	zineb	sulfur
Beets	Cercospora leaf spot	zineb	copper
	Downy mildew	zineb	copper
	Leaf spots	zineb	none available
	Seed treatments	zineb	thiram
Blackeyed beans	Rust	maneb	none available
Broccoli	Alternaria leaf spot	maneb	chlorothalonil
	Downy mildew	maneb zineb	chlorothalonil
	Leaf spots	zineb	chlorothalonil

*Based on a survey of extension plant pathologists coordinated by W. R. Stevenson, utilizing information contained in EPA microfiche registration files and product labels.

**Alternatives limited to those products the survey found to be presently used.

Plant	Disease	Registered EBDC	Alternative** Fungicide
Brussels sprouts	Alternaria leaf spot	maneb	chlorothalonil
	Downy mildew	maneb zineb	chlorothalonil
	Leaf spots	zineb	chlorothalonil
Cantaloupe	Alternaria leaf spot	zineb	captafol anilazine chlorothalonil
	Angular leaf spot	zineb	copper captan
	Anthracnose	mancozeb maneb zineb	anilazine chlorothalonil captan captafol folpet benomyl
	Blossom blight	zineb	copper
	Cercospora leaf spot	maneb	chlorothalonil
	Downy mildew	mancozeb maneb Polyram zineb	anilazine chlorothalonil captafol folpet
	Gummy stem blight	mancozeb maneb Polyram zineb	captafol chlorothalonil anilazine benomyl
	Scab	mancozeb	captafol chlorothalonil
Carrot	Alternaria blight	maneb zineb	chlorothalonil
	Cercospora blight	mancozeb maneb zineb	captan chlorothalonil

Plant	Disease	Registered EBDC	Alternative** Fungicide
Cassaba melon	Alternaria leaf spot (blight)	zineb	captafol anilazine chlorothalonil
	Angular leaf spot	mancozeb	captan copper
	Anthracnose	mancozeb maneb zineb	captafol anilazine captan captafol benomyl folpet
	Blossom blight	zineb	copper
	Cercospora leaf spot	mancozeb maneb	chlorothalonil anilazine
	Downy mildew	mancozeb maneb zineb	captafol anilazine chlorothalonil folpet
	Gummy stem blight	mancozeb maneb zineb	captafol chlorothalonil anilazine benomyl
	Scab	mancozeb zineb	captafol chlorothalonil
Cauliflower	Alternaria leaf spot	maneb	chlorothalonil
	Downy mildew	maneb zineb	chlorothalonil
	Leaf spots	zineb	chlorothalonil
Celery	Early blight and late blight (Cercospora and Septoria)	mancozeb maneb Polyram zineb	chlorothalonil anilazine copper benomyl
Chinese cabbage	Downy mildew	zineb	chlorothalonil
	Leaf spots	zineb	chlorothalonil

Plant	Disease	Registered EBDC	Alternative** Fungicide
Collards	Alternaria leaf spot	maneb	none available
	Downy mildew	maneb zineb	none available
	Leaf spots	zineb	none available
Corn (sweet)	Helminthosporium leaf blight	mancozeb maneb Polyram	chlorothalonil
Crenshaw melons	Alternaria leaf blight	mancozeb zineb	captafol anilazine chlorothalonil
	Angular leat spot	zineb	copper copper
	Anthracnose	maneb zineb	folpet anilazine chlorothalonil captan captafol benomyl
	Blossom blight	zineb	copper
	Cercospora leaf spot	mancozeb maneb	chlorothalonil anilazine
	Downy mildew	mancozeb maneb zineb	anilazine chlorothalonil captafol folpet
	Gummy stem blight	mancozeb maneb zineb	captafol chlorothalonil anilazine benomyl
	Scab	mancozeb zineb	captafol chlorothalonil
Cucumber	Alternaria leaf spot	mancozeb maneb Polyram zineb	captafol chlorothalonil anilazine

Plant	Disease	Registered EBDC	Alternative** Fungicide
Cucumber (Cont'd.)	Angular leaf spot	maneb zineb	copper captan
	Anthracnose	mancozeb maneb zineb	captan captafol chlorothalonil folpet anilazine benomyl
	Blossom blight	zineb	copper
	Downy mildew	mancozeb maneb Polyram zineb	captafol chlorothalonil folpet captan anilazine copper
	Fruit rots	maneb	folpet captan chlorothalonil
	Gummy stem blight	mancozeb Polyram zineb	captafol anilazine chlorothalonil benomyl
	Scab	mancozeb zineb	captafol anilazine chlorothalonil
Eggplant	Anthracnose	maneb zineb	captan
	Cercospora leaf spot	zineb	none available
	Down mildew	zineb	none available
	Early blight (Alternaria)	maneb zineb	none available
	Fruit rots	zineb	captan
	Late blight (Phytophthora)	zineb	none available
	Phomopsis	maneb zineb	captan

Plant	Disease	Registered EBDC	Alternative** Fungicide
Honeydew melons	Alternaria blight	mancozeb zineb	captafol anilazine chlorothalonil
	Angular leaf spot	zineb	copper captan
	Anthracnose	mancozeb maneb zineb	anilazine chlorothalonil captafol folpet benomyl
	Blossom blight	zineb	copper
	Cercospora leaf spot	mancozeb maneb	chlorothalonil anilazine
	Downy mildew	mancozeb maneb zineb	anilazine chlorothalonil captafol folpet
	Gummy stem blight	mancozeb maneb zineb	captafol chlorothalonil anilazine benomyl
	Scab	mancozeb zineb	captafol chlorothalonil
Kale	Alternaria	maneb	none available
	Downy mildew	maneb zineb	none available
	Leaf spots	zineb	none available
Lettuce	Botrytis blight and rot	zineb	copper
	Downy mildew	maneb zineb	copper

Plant	Disease	Registered EBDC	Alternative** Fungicide
Persian melon	Alternaria blight	mancozeb zineb	captafol anilazine chlorothalonil
	Angular leaf spot	zineb	copper captan
	Anthracnose	mancozeb maneb zineb	anilazine chlorothalonil captan captafol folpet benomyl
	Blossom blight	zineb	none available
	Cercospora leaf spot	mancozeb maneb	chlorothalonil anilazine
	Downy mildew	mancozeb maneb zineb	anilazine chlorothalonil captafol folpet
	Gummy stem blight	mancozeb maneb zineb	captafol chlorothalonil anilazine benomyl
	Leaf spots	mancozeb maneb	anilazine
	Scab	mancozeb zineb	captafol chlorothalonil
Mushroom	Brown spot (Verticillium)	zineb	benomyl
	Cobweb (Dactylium)	zineb	none available
	Mildew	zineb	none available
	Soft rot	zineb	none available
Lettuce	Botrytis blight and rot	zineb	copper
	Downy mildew	maneb zineb	copper

Plant	Disease	Registered EBDC	Alternative** Fungicide
Muskmelon	Alternaria blight	mancozeb zineb	captafol anilazine chlorothalonil
	Angular leaf spot	zineb	captan copper
	Anthracnose	mancozeb maneb zineb	anilazine chlorothalonil captan captafol benomyl folpet
	Blossom blight	zineb	copper
	Cercospora leaf spot	mancozeb maneb	chlorothalonil anilazine
	Downy mildew	mancozeb maneb zineb	anilazine chlorothalonil captafol folpet
	Gummy stem blight	mancozeb maneb zineb	captafol chlorothalonil anilazine benomyl
	Scab	mancozeb zineb	captafol chlorothalonil
Onion	Botrytis blight and neck rot	mancozeb maneb zineb	anilazine chlorothalonil captafol
	Down mildew	mancozeb maneb	captafol folpet
	Neck rot	mancozeb	none available
	Purple blotch	mancozeb maneb zineb	anilazine captafol folpet
	Smut	mancozeb	thiram

Plant	Disease	Registered EBDC	Alternative** Fungicide
Peas	Damping off	zineb	captan
	Downy mildew	zineb	none available
	Rust	zineb	none available
Potato	Early blight	mancozeb maneb Polyram	anilazine captafol chlorothalonil
	Late blight	mancozeb maneb Polyram	anilazine captafol chlorothalonil copper
	Scab	mancozeb Polyram	none available
	Seed piece treatment	mancozeb zineb Polyram	captan
Pumpkin	Alternaria blight	zineb	chlorothalonil anilazine
	Angular leaf spot	maneb zineb	captan copper
	Anthracnose	zineb	captan chlorothalonil folpet
	Downy mildew	maneb zineb	chlorothalonil folpet anilazine
	Gummy stem blight	zineb	chlorothalonil anilazine
	Scab	zineb	chlorothalonil
Radish	Alternaria leaf spot	zineb	none available
	Downy mildew	zineb	none available
	Leaf spots	zineb	none available

Plant	Disease	Registered EBDC	Alternative** Fungicide
Spinach	Anthracnose	maneb zineb	none available
	Cercospora leaf spot	maneb zineb	none available
	Downy mildew	maneb zineb	captan
	White rust	maneb	captan
Squash	Alternaria leaf spot	mancozeb zineb	anilazine chlorothalonil
	Angular leaf spot	zineb	copper captan
	Anthracnose	mancozeb maneb zineb	anilazine chlorothalonil captan folpet
	Cercospora leaf spot	mancozeb	anilazine chlorothalonil
	Downy mildew	mancozeb maneb zineb	folpet anilazine chlorothalonil
	Gummy stem blight	mancozeb zineb	chlorothalonil anilazine
	Pythium fruit rot	maneb	none available
	Scab	mancozeb zineb	chlorthalonil
Tomato	Anthracnose	mancozeb Polyram zineb	chlorothalonil captan folpet captafol anilazine
	Bacterial spot	mancozeb maneb	copper
	Black mold (Alternaria)	mancozeb	chlorothalonil captafol

Plant	Disease	Registered EBDC	Alternative** Fungicide
Tomato (Cont'd.)	Early blight	mancozeb maneb Polyram zineb	chlorothalonil captafol anilazine copper
	Gray leaf spot (Stemphylium)	maneb Polyram	anilazine chlorothalonil captan captafol
	Gray leaf mold	mancozeb zineb	chlorothalonil benomyl
	Late blight	mancozeb maneb Polyram zineb	chlorothalonil captafol anilazine
	Nailhead spot	zineb	captafol
	Septoria leaf spot	maneb zineb	captan anilazine
	Southern blight	zineb	none available
Turnip	Downy mildew	maneb zineb	none available
	Leaf spots	maneb zineb	none available
Watermelon	Alternaria leaf spot	mancozeb maneb	anilazine chlorothalonil
	Angular leaf spot	zineb	copper captan
	Anthracnose	mancozeb maneb zineb	ahlorothalonil anilazine captafol captan folpet
	Blossom blight	zineb	copper

Plant	Disease	Registered EBDC	Alternative** Fungicide
Watermelon (Cont'd.)	Downy mildew	mancozeb maneb zineb	chlorothalonil captafol folpet
	Gummy stem blight	mancozeb maneb zineb	anilazine captafol chlorothalonil
	Leaf spots	mancozeb maneb	anilazine chlorothalonil
	Scab	mancozeb zineb	chlorothalonil

TABLE 2. EBDC Fungicides and Registered Alternatives on Sweet Corn

Fungicide	No. of Applications	Rate	Program Cost per Acre Dollars
Maneb, Maneb + Zinc	11.1	1.5 lbs	25.39
Mancozeb	11.1	1.5 lbs	25.39
Zineb	11.1	2.0 lbs	31.75
Metiram	11.1	3.0 lbs	46.62
Capafol	11.1	1.5 qts	50.99
Chlorothalonil	11.1	1.5 pts	58.28

TABLE 3. EBDC Fungicides and Registered Alternatives on Celery

Fungicide	No. of Applications	Rate	Program Cost per Acre Dollars
Maneb, Maneb + Zinc	20.2	1.5 lbs	46.21
Mancozeb	20.2	1.5 lbs	46.21
Zineb	20.2	2.0 lbs	57.77
Metiram	20.2	2.0 lbs	56.56
Benomyl	20.2	0.5 lbs	90.90
Chlorothalonil	20.2	1.5 pts	106.05
Copper	20.2	2.0 lbs	79.70
Anilazine	20.2	4.0 lbs	242.40
Thiram	20.2	2.0 lbs	54.54
Dichlone	20.2	1.0 lbs	95.95

TABLE 4. EBDC Fungicides and Registered Alternatives on Peppers

Fungicide	No. of Applications	Rate	Program Cost per Acre Dollars
Maneb Maneb + Zinc	7.6	1.5 lbs	17.39
Zineb	7.6	2.0 lbs	21.74
Copper	7.6	4.0 lbs	53.20

TABLE 5. EBDC Fungicides and Registered Alternatives on Cabbage

Fungicide	No. of Applications	Rate	Program Cost per Acre Dollars
Maneb Maneb + Zinc	4.9	1.5 lbs	11.21
Zineb	4.9	2.0 lbs	14.01
Chlorothalonil	4.9	1.5 pts	25.73

TABLE 6. Fresh Market Tomatoes, Acres Planted, Acres Treated

Selected States	Acres Planted	Acres Treated	Percent
New Jersey	6,900	3,000	43
Maryland	2,400	1,000	42
Virginia	2,500	1,000	40
South Carolina	8,000	8,000	100
Georgia	3,100	3,100	100
Michigan	4,400	4,400	100
Alabama	8,500	7,500	88
New York	3,200	1,000	31
North Carolina	2,100	2,100	100
Florida	39,300	37,795	96
California	29,400	3,140	11
Total Selected States	109,800	72,035	

1. Marketing Florida Sub-Tropical Fruits and Vegetables. Summary 1975-76, Federal-State Market News Service, P. O. Box 19246, Orlando, Florida 32814, June 1, 1976.

2. Vegetables-Fresh Market, 1976 Annual Summary, Acreage, Yield, Production and Value Crop Reporting Board, Vg. 2-2 (77) Statistical Reporting Service, USDA, Washington, D. C. 20250.

TABLE 7. Fresh Market Tomatoes, Number of Spray Applications, Rate per Acre per Application, Active Ingredient per Acre per Application, and Quantity of EBDC Used.

Selected States	Number of Applications	Formulation/Acre per Application	Active Ingredient/ Acre/Application	Estimated Total Quantity Used
New Jersey	6	2.5	2.0	36,000
Maryland	6	3	2.4	14,400
Virginia	6	3	2.4	14,400
South Carolina	8	1.75	1.4	85,120
Georgia	4	2	1.6	18,560
Michigan	8	2	1.6	55,040
Alabama	7	2.5	2.0	105,000
New York	5	3	2.4	12,000
North Carolina	10	1.5	1.2	24,000
Florida	21.6	1.85	1.5	1,216,800
California	4	2.5	2.0	25,120
Total Selected States				1,606,440

TABLE 8. Fresh Market Tomatoes, Average Yield per Acre, Yield with No EBDC and Percent Loss with No EBDC.

Selected States	Ave. Yield/Acre 74-76	Estimated Yield No Treatment	Estimated % Loss in Yield no Treatment
	CWT	CWT	
New Jersey	86	60 - 69	20 - 30
Maryland	99	69 - 79	20 - 30
Virginia	127	89 - 102	20 - 30
South Carolina	87	61 - 70	20 - 30
Georgia	69	48 - 55	20 - 30
Michigan	92	64 - 74	20 - 30
Alabama	66	46 - 53	20 - 30
New York	122	85 - 98	20 - 30
North Carolina	148	104 - 118	20 - 30
Florida	236	0 - 118	50 - 100
California	230	184 - 207	10 - 20

1. In each of the above states, Bravo appears to be the preferred alternative. This material would be applied at a rate of 2.0 lb. per acre at the same frequency and total number of applications as EBDC.

TABLE 9. EBDC Fungicides and Registered Alternatrives on Tomatoes

Fungicide	Number of Applications	Rate Formulation	In Dollars Program Cost per Acre
Maneb, maneb + zinc	21.6	1.85 lbs	60.94
Mancozeb	21.6	1.85 lbs	60.94
Zineb	21.6	3.00 lbs	92.66
Metiram	21.6	2.00 lbs	60.48
Benomyl	21.6	0.50 lb	97.20
Captan	21.6	6.00 lbs	160.70
Captafol	21.6	2 qts	132.30
Chlorothalonil	21.6	3 qts	226.80
Copper[1]	21.6	2.00 lbs	75.60
Anilazine	21.6	3.00 lbs	194.40
Ziram	21.6	3.00 lbs	
Dichlone	21.6	1.00 lb	102.60

[1]Copper hydroxide (basic, and resins 50%) is not used exclusively throughout crop season since it is not as effective as major alternatives and is toxic to the plant.

TABLE 10. Acreage of the Major Areas (States) Growing Tomatoes for Processing in the United States in 1976.

State	Acres Planted
California	267,7000
Indiana	14,300
Maryland	4,400
Michigan	4,100
New Jersey	9,400
Ohio	22,600
Pennsylvania	6,500

TABLE 11. Acres of Processing Tomatoes Treated with EBDC Fungicides in 1976

State	Acres Treated	Percent of Total Acres Planted Which Were Treated
California	23,686	9
Indiana	12,000	84
Maryland	2,200	50
Michigan	3,000	73
New Jersey	6,000	64
Ohio	22,300	99
Pennsylvania	4,500	69

TABLE 12. Registered Alternative Compounds Recommended for Control of Tomato Diseases in Various States.

Disease	EBDC's Recommended	Alternatives Recommended
Early	Yes	Chlorothalonil captafol anilazine dichlone captan folpet ziram ferbam
Anthracnose	Yes	chlorothalonil captafol anilazine copper folpet captan benomyl ziram ferbam
Late Blight	Yes	chlorothalonil captafol anilazine copper captan folpet
Septoria	Yes	chlorothalonil anilazine copper captafol folpet captan benomyl
Grey Leaf Spot	Yes	chlorothalonil anilazine captafol benomyl captan folpet copper
Botrytis Mold	Yes	benomyl chlorothalonil anilazine dichloran copper captan thiram ferbam

TABLE 13. Estimated Pounds of EBDC Fungicides Used in Seven States on Processing Tomatoes in 1976.

State	Average Number Applications/Season	Lb. (AI)/Acre/ Application	Total lb. Applied/Season
California	2	2.0	94,744
Indiana	8	2.0	192,000
Maryland	8	2.0	35,200
Michigan	8	2.0	48,000
New Jersey	8	2.0	96,000
Ohio	8	2.0	356,800
Pennsylvania	8	2.0	72,000

TABLE 14. The Effect of Fungicidal Sprays on Yield and Disease Control of Processing Tomatoes Over a Twelve-Year Period (1964-1976) at the University of Maryland Vegetable Farm, Salisbury, Maryland.

Treatment	Rate/Acre (ai)	Yield (Tons/Acre)	Disease Control: Percent Anthracnose	Disease Control: Percent Defoliation from Early Blight
Control (Unsprayed)	——	13.9	27.5	81
Maneb	2.4 lb	20.5	8.1	35
Captafol	2.0 lb	23.5	4.9	27
Chlorothalonil	1.9 lb	24.3	5.2	29

1/Eight application applied on a 7-day schedule.

2/Mean of 10 experiments (1964, 1965, 1967-1973, 1976).

TABLE 15. Comparison of Results for Control of Lima Bean Downy Mildew at the University of Maryland Vegetable Farm, Salisbury, Maryland.

Material	Concentration	Percent Infected Pods: Test #1	Percent Infected Pods: Test #2	Pounds Shelled Beans/Acre: Test #1	Pounds Shelled Beans/Acre: Test #2
Untreated	——	38.0	34.0	2523	1842
Maneb	2 lb/100 gal	0.4	1.0	3819	3991
Tribasic Copper	4 lb/100 gal	9.0	2.0	3248	3435
Streptomycin	100 ppm	25.0	14.0	2438	2282

TABLE 16. Some Diseases of Vegetables Controlled by EBDC Fungicides for Which No Registered Alternative Fungicide Exists.

Crop	Disease
Beans	Anthracnose
Collards	Downy mildes Alternaria Cercospora White spot White rust
Eggplant	Leaf blights Cercospora Downy mildew
Endive	Alternaria Downy mildew White rust Grey mold
Escarole	Downy mildew Alternaria
Kohlrabi	Alternaria Downy mildew
Lentils	Leaf & Stem spots Blights
Peas	Downy mildew Rust
Radish	Alternaria leaf spot Downy mildew Leaf spots
Romaine	Downy mildew
Rutabaga	Downy mildew
Spinach	Anthracnose Cercospora leaf spot
Swiss Chard	Downy mildew
Turnip	Downy mildew Leaf spots

POTATOES

Potatoes are grown in every state within the continental United States, including Alaska. It is estimated that about 353,386,000 cwt of potatoes were produced on approximately 1,374,100 acres in 1976. In 1976, 32% (439,712 acres) of the potatoe acreage was east of the Mississippi River and 68% west of it. Approximately 58% of the acreage was located in the top five potato producing states: Idaho, Maine, Minnesota, North Dakota, and Washington (USDA SRS CRB Crop Produc- tion 1976 Annual Summary Jan. 17, 1977).

Fungicide Uses

Fungicidal sprays are used to control two major foliar diseases of potatoes; namely late blight caused by *Phytophthora infestans* (Mont) de Bary and early blight caused by *Alternaria solani* (Ell. & G. Martin). L. R. Jones & Grout. Fungicidal sprays also are suggested for the control of Botrytis leaf spot and vine rot caused by *Botrytis* sp. in some states. Fungicidal dusts are applied to the seedpieces before planting for the control of *Fusarium* seedpiece decay caused by several species of *Fusaria*, Rhizoctonia stem canker caused by *Rhizoctonia solani* kuhn, common scab caused by *Streptomyces acabies* (Thaxt.) Waks. & Henrici., *Verticillium* wilt caused by *Verticillium albo-atrum* Reinke & Berth. and other pathogens that may be carried on the seed tubers. None of these uses involve application directly to the plant part that is harvested and eaten (the tubers).

Foliar sprays are used primarily for the control of late blight in the Eastern Region of the United States. Most fungicides that are recommended for the control of late blight will also control early blight (Harrison & Venette 1970). Since late blight, in areas where it occurs, can and usually does cause more damage to the potato crop than early blight, more work has been done on the development of fungicides for the control of late blight than for early blight.

Late Blight

Late blight was the cause of the 1845-46 potato famine in Ireland and has been reported as occurring in most, if not all, major potato production areas of the world as well as the United States (Cox and Large 1960). Approximately 47% of the potato acreage in the United States is exposed to late blight to one degree or another. It occurs mainly in those areas with high rainfall and/or high relative humidity (90% or more) for ten or more consecutive hours on one or more days per week during the growing season. Consequently, it is a constant threat to the potato industry along the Atlantic coast; valley areas of most mountainous regions; along lakes, rivers, and streams; in muck soil areas of the Northeast and Midwest, and in coastal and localized irrigated areas of the Pacific Northwest.

Yield losses due to late blight depend upon when the epidemic begins in relation to plant and tuber development and how rapidly

epidemic develops (James et al 1972, Mackenzie and Petruzzo 1975, and Latin et al 1978), and both are dependent upon moisture and temperature in the macro- and micro-environment. Under optimum conditions the late blight fungus can complete its life cycle in 4-5 days (Crosier 1934, Cox and Large 1960). Under most field conditions, however, the time required for completion of the cycle from inoculation to lesion formation and spore production is 5 to 10 days. Since spore production and disease development is geometric, the initial phases in the development of a late blight epidemic are relatively slow and may go undetected. Once the inoculum potential in a field or area reaches a given point, the development of the epidemic is rapid, devastating and uncontrollable, even with broad usage of the maximum label rate of the effective protective fungicides commercially available. Consequently, to obtain maximum control of late blight, growers must apply a protective fungicide before an epidemic begins and continue to apply it on a 7- to 10-day schedule during the remainder of the growing season. This is especially true in the Gulf, New England, and Great Lake States where late blight is most likely to occur, because the potato plant produces new unprotected foliage throughout most of the growing season, residue on the foliage decreases as a result of weathering and degradation of the fungicide deposit, and weather forecasters cannot accurately predict several days in advance when environmental conditions will be favorable for the disease.

In the late 1800's and early 1900's when potato farmers either did not apply a fungicidal spray or dust, or did apply them with

equipment that was not adequate for the job, late blight occurred almost every year in several states along the Atlantic Coast (USDA 1917 - Plant Dis. Bull. No. 6 Nov. 1, 1917, USDA 1922 - Plant Dis. Bull. 24:489-510). Even today with the widespread use of modern application equipment and more effective fungicides, late blight usually occurs in one or more states along the Atlantic Coast each year. The widespread use of effective protective fungicides, such as the EBDC's, captafol and chlorothalonil, keeps the losses to a minimum, probably less than 5% for the potato industry as a whole in the affected regions. The potential losses, however, if no effective fungicide was available or permitted to be used, could be in the range of 30 to 40% for affected areas and as high as 100% for individual growers (Table 1) (James et al 1972, Latin et al 1978, MacKenzie and Petruzzo 1975, and Plank 1963). Most modern day late blight epidemics occur as a result of growers' inability to apply the protective fungicidal sprays during extended periods of wet weather, which is favorable for late blight development. The losses due to late blight are (1) a reduction in yield due to premature death of the plants, (2) tuber rot that develops in the field before harvest, (3) tuber rot that develops in storage after harvest, (4) increased labor costs to sort infected lots to U. S. No. 1 grade standards, (5) reduced price received for shipments rejected at points of destination, and (6) regrading and repacking costs at the wholesale and retail levels. Most of these losses are prevented by application of effective protective fungicidal sprays during the growing season.

Early Blight

Early blight occurs in every major U. S. potato producing region. Nearly 100% of potato acreage in the United States is exposed to early blight. The importance of this disease, however, varies with the cultivar grown and the environment during any given growing season. The early blight fungus is not restricted by the same conditions of high humidity and moderate temperatures as the late blight pathogen. Although high rates of water application under sprinkler irrigation favor secondary spread of this fungus, it is adapted to relatively arid conditions and high daytime temperatures. It is for this reason that, even though late blight is the more serious threat, early blight is more widespread in North America.

Approximately 53% of U. S. potato acreage is not exposed to late blight and in these regions, early blight is the major disease problem for which foliar fungicides are used. Early blight is effectively controlled by successive applications of the same fungicides used to control late blight. From two to four applications per season are normally sufficient. The disease typically affects maturing plants which have already produced a considerable portion of their yield. Losses, even without control, are therefore somewhat less than is generally true of uncontrolled late blight. The Russet Burbank is the predominant cultivar grown in areas in which early blight is the major foliar disease problem. This is a relatively resistant variety which helps make early blight a less

serious threat to U. S. potato production. Even so, yield increases of up to 22% have been obtained with fungicidal control of early blight on the Russet Burbank cultivar in perennial problem areas (Douglas and Garner 1974). Because of the large acreage affected, even marginal disease problems (less than 10% yield loss) in most years would amount to a very great actual production loss. If early varieties or more susceptible late varieties were to be grown, the early blight problem would be magnified.

The early blight fungus can also infect the tuber at harvest and cause considerable loss in storage--both as direct rot loss and even more important, loss of quality in the tubers removed from storage. Infected tubers have low quality from several standpoints. Lower grade and higher trim loss are the most obvious. Less obvious are the levels of metabolites produced as a result of infection, which pose an as yet undefined health hazard to the consumer. Fungicidal control of foliar blight development reduces the inoculum potential for the tuber at harvest and may decrease the amount of tuber rot that develops in storage.

Seedpiece Treatment

The primary target for seedpiece treatment is Fusarium seedpiece decay. Since the fungus can be found in most, if not all, potato soils and on the surface of most, if not all, tubers (Cunningham and Reinking 1946), 100% of the potato acreage is

exposed to this malady. Seedpiece decay can reduce yields by reducing plant vigor and stands.

Before seedpiece treatment became a common practice in the late 1940's, stand reductions of 10 to 90%, due to Fusarium seedpiece decay, were common (Cunningham and Reinking 1946). When stands were seriously reduced, growers either replanted the affected fields to potatoes or to some other crop. Replanting of potatoes was costly and usually resulted in reduced yields as a result of the late planting date. The early seedpiece treatments involved dipping the whole tubers in suspensions of Semesan Bel (a mercurial compound) or solutions of nabam (Cunningham and Reinking 1946). These treatments reduced the population of the seedpiece rotting organisms on the surface of the whole tubers but did not protect the cut surfaces from contamination and invasion by the <u>Fusaria</u> fungi and other seedpiece decaying organisms (Cetas 1966b F & N Tests - 1965). Consequently, stand reduction due to Fusarium decay often was a problem even though the whole tubers had been dipped in either a mercurial suspension or nabam solution. In 1953 Rulhe demonstrated that captan dust would reduce the losses due to seedpiece decay (APS - Agric. Chem. 9(2):5862,125-129). Manzer and Merriam (Table 8) (Manzer and Merriam 1967 - F & N Tests 22:114-115) found that the 7% metiram dust provided better control of scab than the 10% captan dust. Tests conducted in 1967 and 1968 demonstrated that mancozeb dusts would control Fusarium seedpiece decay, Rhizoctonia stem canker and scab (Cetas 1968 - F & N Tests 23:120, Cetas 1969 - F & N Tests 24:111 and Manzer and Merriam 1969 - F & N Tests 24:112-113).

The 8% mancozeb dust became commercially available in the late 1960's and is currently used by more growers than either 7.5% or 10% captan or 7% metiram dust for the control of Fusarium seedpiece decay, Rhizoctonia stem canker and/or scab in the United States.

Fungicides are always recommended for potatoes as part of the crop management program. Along with pesticide application, this includes use of disease-free seed stock, complete healing of cut seed, removal of diseased material, crop rotation, the use of cultural practices which favor the potato and suppress pests, and the use of resistant varieties where feasible. The major EBDC alternatives for foliar use (captafol and cholorthalonil) can give equivalent control of early blight and late blight at somewhat higher costs. Captan, the only viable alternative as seed-piece treatment, does not give comparable control of all pathogens associated with the seedpiece. Due to the large quantities of EBDC used (approximately 60% of all early blight treatment, 65% of all late blight treatment, and 65% of all seedpiece treatment in the United States), alternatives would have to be manufactured in large enough quantity to supply all of the immediate demands should EBDC registration be dropped. The registration of two of the three major alternatives, captan and the captan derivation captafol, is being questioned in pre-RPAR reviews, limiting alternatives even further. A potential problem of unknown impact would be the possibility of the loss of effectiveness of these alternatives due to fungal resistance. The copper fungicides, which were phytotoxic and of lower efficacy, and the EBDC's have historically been the major

treatments for early and late blight. No fungal resistance to these materials has developed because of the multiple sites of inhibition apparently involved.

SUMMARY OF EFFICACY DATA FOR EBDC's AND VIABLE ALTERNATIVES

Late Blight

In all tests conducted from 1972-1976, EBDC's reduced the rate at which late blight epidemics developed. When the epidemics were initiated early enough, their use reduced the yield losses due to late blight. In many tests, the EBDC's did not control the foliar blights as well as captafol or chlorothalonil, but were more efficacious than the copper fungicides included in a few tests (Tables 2, 3, and 4) (Baldwin 1973a; Callbeck 1973, 1974, 1975, 1977; Cetas 1973a, 1974a, 1975a, 1976a, 1977a, 1978; Krause et al 1974, 1975; Manzer and Merriam 1973, 1974, 1975; Manzer et al 1976a, 1977a; Rowe 1977a; Wade and Wies 1974a; Weingartner 1973a, 1973b).

Early Blight

The information on benefits of early blight control falls into two categories:

1. Total yield benefits with treatment: Average maximum losses of 18% with no treatment for all trials reviewed.

2. Benefits in increases in quality of potatoes: Average maximum losses of 26% in U. S. No. 1's with no tretment for all trials reviewed.

It is generally believed that control of foliar blight provides some protection to the tubers at hervest by lowering the inoculum potential. Since there is no documentation available for the prevention of loss of quality in stored potatoes through foliar treatment, the benefits in maintenance of storage quality through foliar fungicide applications cannot be assessed at this time. Chlorothalonial and captafol appear to give equal or slightly better control (Table 5) (Douglas and Groskopp 1974; Douglas and Garner 1974; Harrison et al 1965a, b,c; Harrison and Venetta 1970; Hugelet 1976; Manzer et al 1976b, 1977b).

Seedpiece Decay and Other Seedpiece Related Diseases

The results of the seedpiece treatment tests reviewed for this report demonstrate the ability of the captan, mancozeb, and metiram dusts to control three diseases of potatoes caused by seedpiece-borne pathogens: *Fusarium* seedpiece decay, *Rhizoctonia* stem canker and scab. Under high inoculum pressures, the mancozeb dust often provided better control of Fusarium seedpiece decay than either captan or metiram dust (Table 6) (Baldwin 1973b, 1974, 1975, 1976; Cetas 1973b, 1974b, 1975b, 1976b, 1977b; Weingartner 1974). Captan dusts, however, often were equal to or better than the EBDC dusts for the control of *Rhizoctonia* stem canker (Table 7) (Abdel-Rahman 1975, Cetas 1973c, 1974c, 1975c, 1976c, 1977c; Rowe 1977b). Tests conducted in Maine indicate that the EBDC dusts are more effective than captan dusts for the control of scab (Table 8) (Manzer and Merriam 1965, 1966, 1967, 1968, 1969; Manzer, Merriam and Alexander

1970, 1971, 1972); but on Long Island, New York, captan usually controlled scab as well as the EBDC's (Table 9) (Cetas 1973d, 1974d, 1975d, 1976d, 1977d). The dust treatments often improved the vigor and stand of plants and yield of tubers as a result of controlling seedpiece decay and/or Rhizoctonia stem canker. When applied to scabby seedpieces, the treatments usually decreased the incidence of scabby tubers at harvest and occasionally decreased the severity of scab on the affected tubers. In addition to controlling Fusarium seedpiece decay, Rhizoctonia stem canker and scab, the results of some tests reviewed for this report indicate that the captan and EBDC dust treatments may reduce the losses due to blackleg, Verticillium wilt and other diseases caused by pathogens carried on the seedpieces (Table 7) (Abdel-Rahman 1975, Line and Eide 1961, Stanghellini 1972, Weingartner 1974).

Alternatives for EBDC's

The only viable alternatives for the EBDC fungicides are captafol and chlorothalonil. The results of the various tests summarized in Tables 2 through 5 indicate that captafol and chlorothalonil will control late and early blight as well as or slightly better than any of the EBDC fungicides. Their use, however, did not result in yields that were significantly greater than those obtained from the use of the EBDC fungicides. In general, the use of captafol or chlorothalonil resulted in less late blight tuber rot. The results of some tests (Table 4) indicate that the foliar residues of captafol and of chlorothalonil will provide better protection against

late blight over a longer period of time than the residues of the EBDC fungicides, especially during periods of rainy wet weather when ground applications are impossible.

The per acre cost of controlling late blight of potatoes in 1976 was about $18.00 with an EBDC fungicide, $23.00 with captafol, and $32.00 with chlorothalonil. The removal of the EBDC's from the market would result in an increase in the cost of producing potatoes and in either an increase in the price of potatoes to the consumer or a decrease in net income for the potato farmer or both. The only viable alternative to the EBDC fungicidal dusts for treating seedpieces for control of the various seedpiece-borne diseases is captan. As indicated earlier, captan dust is not as effective as mancozeb or metiram dust for the control of *Fusarium* seedpiece decay, especially when the inoculum potential is high. Captan, however, often is equal or superior to the EBDC fungicides for the control of *Rhizoctonia* stem canker. Captan was equal to mancozeb and metiram for the control of scab on Long Island, New York, but failed to control scab satisfactorily in Maine. Since the cost of captan dust is about the same as for mancozeb and metiram dust, the loss of the EBDC fungicidal dusts for treating potato seedpieces probably would have little or no effect on the cost of potato production. Their loss, however, would reduce the arsenal of fungicides that growers have available for controlling, at least in part, diseases that are caused by the complex of pathogens that are carried on seed tubers.

TABLE 1. Potential Yield Losses Due to Late Blight[1/]

State	Year	Cultivar	% Defoliation		cwt per Acre		Loss	
			Treated[2/]	Check[3/]	Treated[2/]	Check[3/]	cwt/A	%
Wisconsin	1972	Russet Burbank	7	48	203	180	23	11.3
Wisconsin	1973	Ruset Burbank	22	92	344	299	45	13.1
Maine	1973	Katahdin	3	71	290	243	47	16.2
Maine	1972	Katahdin	16	100	388	314	74	21.9
Maine	1972	Katahdin	5	100	392	293	99	25.3
Maine	1973	Katahdin	1	84	271	199	72	26.6
Pennsylvania	1975	?	54	100	342	248	94	27.5
Florida	1972	Red La Soda	2	100	241	172	69	28.6
Maine	1974	Katahdin	7	87	313	209	104	33.2
Maine	1976	Katahdin	2	83	337	218	119	35.3
New York	1975	Hudson	5-10	80-100	321	203	118	36.8
Pennsylvania	1974	Kennebec	43	95	207	207	137	39.8
New York	1975	Katahdin	1-5	80-100	226	130	96	42.5
Maine	1974	Katahdin	3	98	339	179	160	47.2
Pennsylvania	1974	Kennebec	62	99	329	152	177	53.8
New York	1976	Hudson	13	100	334	158	176	52.7
Michigan	1973	Russet Burbank	23	71	148	37	111	75.0

[1/] Data for this table taken from annual reports of fungicide trials published in Fungicide and Nematicide Tests, Volumes 28, 29, 30, 31, and 32, published by the Amer. Phytopathological Society in 1973, 1974, 1975, 1976, and 1977, respectively.

[2/] Plots sprayed with either an EBDC, captafol or chlorothalonil fungicide.

[3/] Plots not sprayed with a fungicide. Otherwise treated the same as those sprayed with a fungicide.

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Table 2. Results of spraying potatoes with various fungicides for the control of early and late blights in Wisconsin in 1973[1].

Fungicide and formulation[3]	Lb ai/A	% infection: Early blight 30 Aug.	% infection: Early and late blight 20 Sept	Cwt/A
Check (no fungicide)		22.8 a	92 a	299 b
Captafol 4F	1.0-1.5[2]	5.1 c	22 b	344 a
Chlorothalonil 6F	0.75	6.1 c	24 b	343 a
Mancozeb 80W	1.20	10.1 bc	37 b	342 a
Metiram 80W	1.20	10.0 bc	39 b	325 a
Fentin hydroxide 47.5W	0.119-0.178[2]	5.8 c	37 b	356 a

1/ Test conducted on the 'Russet Burbank' cultivar. Small letters indicate Duncan's multiple range groupings of means that do not differ significantly at the 5% level. Wade, E. K. and G. G. Weis. 1974.

2/ Lower dosage applied first four sprays, higher dosage applied during remainder of season.

3/ Fungicides applied weekly beginning 29 June and ending 14 Sept. with a high-pressure sprayer calibrated to apply 30 gal/A at 200 psi. Plots inoculated with *Phytophthora infestans* 30 July and 10 Aug and harvested 10 Oct.

Table 3. Results of foliar fungicide trials at Aroostook Farm, Presque Isle, Maine for the control of late blight of potatoes, 1972-1976[1/].

Fungicide and formulation[9/]	Lb ai/A[2/]	% defoliation	Cwt/A	% tuber rot
		1972[3/]		
Check (no fungicide)		100.0	---[8/]	---
Captafol 4F	0.8-1.6	2.6	414	1.4
Chlorothalonil 6F	0.375-0.75	7.0	420	5.0
Chlorothanonil 75W	0.375-0.75	5.6	381	3.8
Maneb 80W	0.8-1.6	16.0	400	6.7
Mancozeb 80W	0.8-1.6	18.0	409	8.4
Metiram 80W	1.2-2.4	15.8	436	3.5
		1973[4/]		
Check (no fungicide)		71.0	270	2.8
Chlorothalonil 6F	0.75-1.12	0.2	310	0.0
Maneb 80W	0.8	1.0	328	4.6
Mancozeb 80W	0.8-1.6	1.0	324	1.6
Metriam 80W	1.2	2.8	331	4.4
		1974[5/]		
Check (no fungicide)		100.0	---	---
Captafol 4F	0.8-1.6	13.6	349	0.8
Chlorothalonil 6F	0.75	0.0	368	2.6
Mancozeb 80W	0.8-1.6	0.2	374	5.8
Metiram 80W	1.2	6.8	365	7.0

Table 3. Concluded.

Fungicide and formulation 9/	Lb ai/A 2/	% defoliation	Cwt/A	% tuber rot
		1975 6/		
Check (no fungicide)		80.0	---	---
Captafol 4F	0.8	0.0	353	---
Chlorothalonil 6F	0.56	0.0	362	---
Mancozeb 80W	0.8	0.0	351	---
Metiram 80W	1.2	0.0	365	---
		1976 7/		
Check (no fungicide)		100.0		
Chlorothalonil 6F	0.75	2.0	365	---
Mancozeb 80W	0.8-1.6	2.0	350	---

1/ All tests conducted using the 'Katahdin' cultivar. Defoliation data for 'check' taken from buffer rows except in 1973 when 'check' was included in test.

2/ Where two rates are indicated, the higher rate was used for the seventh and succeeding sprays in 1972, after mid-August in 1973, for spray applied week of 5 August and thereafter in 1974 and during periods of high inoculum pressure in 1976.

3/ - 5/ Manzer, F. E. and D. C. Merriam. 1973, 1974 and 1975, respectively.

6/ & 7/ Manzer, F.E., D. C. Merriam and E. A. Giggie. 1976 and 1977, respectively.

8/ --- indicates that data were not taken.

9/ Fungicides applied weekly beginning the second week of July and ending the first or second week of Sept. with high-pressure sprayer calibrated to apply 100 gal/A. Plots inoculated with *Phytophthora infestans* the later part of July and harvested last week of Sept. or first week of Oct.

Table 4. Percent defoliation due to late blight as a result of spraying potatoes with various fungicides on Long Island, New York1/.

Fungicide, formulation	1972 2/	1973 3/	1974 4/		1975 5/		1976 6/	1977 7/	
and lb ai/A/application 9/	3 Oct	9 Oct	17 Sept	4 Oct	30 Sept	10 Oct	28 Sept	27 Sept	11 Oct
None	99 b	94 b	72 b	99 c	96 c	100 d	93 b	70 c	99 c
Chlorothalonil 75W 1.125	8 a	2 a	4 a	6 ab	--- 8/	---	---	---	---
Chlorothalonil 6F 1.125	---	2 a	3 a	4 a	5 a	33 ab	7 a	1 a	10 a
Captafol 4F 1.25	7 a	2 a	3 a	7 ab	5 a	18 a	6 a	1 a	33 b
Mancozeb 80W 1.20	7 a	2 a	6 a	11 b	14 b	74 bc	3 a	3 ab	52 b
Metiram 80W 1.20	6 a	2 a	4 a	8 ab	7 ab	60 bc	5 a	2 a	76 b
Fentin hydroxide 47.5W 0.21	8 a	---	5 a	16 b	17 b	82 c	2 a	---	---

1/ Tests conducted using the 'Green Mountain' cultivar in 1972, 1973, 1974 and the 'Hudson' cultivar in 1975, 1976 and 1977. Small letters indicate Duncan's multiple range groupings that do not differ at the 5% level.

2/ - 7/ Cetas, R. C. 1973a, 1974a, 1975a, 1976a, 1977a and 1978, respectively.

8/ --- indicates fungicide not tested.

9/ Fungicides applied weekly between mid-July and first week of Oct. with a high-pressure sprayer calibrated to apply 100 gal/A, except between 18 and 29 Sept. 1975 and 13 and 29, 1977 when sprays were delayed due to ca. 5 inches of rainfall. Plots inoculated with *Phytophthora infestans* the latter part of August each year.

Table 5. The effect of fungicide applications on early blight infection and potato yield.

Treatment	Rate per acre	Number of applications	1965 Percent infection 7-15	8-2	8-25	Yield (cwt/A) U.S. #1	Total
Control			0.3 a 1/	2.8 a	70.7 a	97.7 a	200.1 a
Manzate D	2.0 lb	6	0.0 b	0.7 b	2.1 b	127.2 b	227.3 b
Manzate D	2.0	4	0.1 a	2.0 a	3.7 b	135.9 b	242.4 b

	Rate per acre	1967 8-10	8-24	9-7 2/	U.S. #1	Total
Sprinkler Irrigation						
Control		4.0 a 1/	33.3 a		46.3 a	104.1 a
Difolatan 80 Wettable	1.5 lb	0.7 b	4.1 b		52.4 a	111.7 a
Difolatan 4 Flowable	1.2 qt	0.9 b	2.5 b			
Manzate D	1.5 lb	0.8 b	1.2 b			
Row Irrigation						
Control		3.1 a 1/	20.7 a	57.0 a	73.8 a	141.5 a
Difolatan 80 Wettable	1.5 lb	1.0 b	3.3 b	4.0 b	87.2 b	158.1 a
Difolatan 4 Flowable	1.2 lb	0.8 b	2.7 bc	4.4 b	89.3 b	159.3 a
Manzate D	1.5 lb	0.6 b	1.8 c	2.1 b	89.9 b	160.5 a

	Rate per acre	1968 8-7	8-20	8-28	U.S. #1	Total
Control		30.8 a 1/	98.9 a	99.8 a	46.2 b	108.1 a
Difolatan 80 Wettable	1.50 lb	3.2 b	14.2 b	15.7 c	49.6 bc	130.4 a
Difolatan 4 Flowable	1.20 qt	1.4 bc	4.3 cd	6.3 ef	60.0 ab	123.5 a
Dacohil 2787	1.50 lb	0.3 c	6.6 cd	4.3 fg	53.1 bc	126.5 a
Daconil 2787	1.00 lb	1.4 bc	5.6 cd	9.6 d	81.7 a	155.6 a
Daconil 2787	0.75 lb	1.2 c	8.7 c	9.1 d	57.7 ab	151.3 a
Daconil 2787	0.50 lb	2.3 bc	18.1 b	22.6 b	65.0 ab	145.2 a
Manzate D	1.50 lb	0.6 c	4.0 d	3.7 g	33.5 c	124.8 a
Manzate D	1.00 lb	0.7 c	5.9 cd	5.8 f	52.9 bc	141.3 a
Manzate D	0.75 lb	0.6 c	7.5 cd	9.2 e	64.6 ab	139.0 a

1/ Means with the same letters do not differ significantly at the 5% level.

2/ Disease evaluations in the sprinkler irrigation plots were not possible on 9-7 due to foliar damage caused by drift of vine killer from adjacent fields.

3/ Harrison & Venette 1970

Table 6. Results of treating potato seedpieces for control of *Fusarium* decay in Virginia, 1974.

Fungicidal treatment	% Stand	% *Fusarium*[1] infection	Yield cwt/A	% Stand	% *Fusarium*[1] infection	Yield cwt/A
		Superior			Norchip	
			1974[4]			
None (not inoculated)	58	95 a	56 a	52 a	98	75 a
None (inoculated)	59	99 a	62 a	64 a	96	101 ab
Captan 7.5% dust	95	51 b	135 b	88 b	68	143 ab
Mancozeb 8% dust	96	30 c	152 b	92 b	48	177 b
Metiram 7% dust	94	55 c	142 b	92 b	42	176 b

Small letters indicate groupings of treatments that are not significantly different at the 5% level.

1/ Percentage of seedpieces with *Fusarium* decay about 20 weeks after treating in 1974.

4/ Baldwin, R. E. 1974.

Table 7. Results of treating potato seedpieces for the control of seedpiece decay, *Rhizoctonia* stem canker and *Verticillium* wilt in 1974[1].

Cultivar and seedpiece treatment	% stand	Disease ratings[2] Rhizoctonia stem canker	Verticillium[3]		Yield cwt/A
			Wilt	Tubers	
'Katahdin'					
None	80 a	3.3 a	2.7 a	4.3 a	167 a
Mancozeb 8% dust	100 b	1.7 b	1.8 b	2.4 b	240 b
'Russet Burbank'					
None	84 a	2.6 a	2.5 a	3.0 a	153 a
Mancozeb 8% dust	100 b	1.2 b	1.6 b	2.5 a	231 b
'Kennebeck'					
None	78 a	3.6 a	3.5 a	4.0 a	163 a
Mancozeb 8% dust	100 b	2.3 b	2.8 b	2.3 b	274 b

1/ Test conducted at the Agway Farm Research Center, Fabius, New York. Abdel-Rahman, M. 1975. Small letters indicate groupings of treatments not significantly different at the 5% level.

2/ Disease ratings were based on a scale of 0 to 5 when 0 represents healthy plants or tubers and 5 severely affected plants or tubers.

3/ Wilt base on plant symptoms in the field and tuber scores based on amount of stem end discoloration after harvest.

Table 8. Results of treating potato seedpieces with various fungicides for the control of scab in Maine, 1966 and 1971.

Type of seed and fungicidal treatment	Lb scabby tubers per plot[1/] light	Lb scabby tubers per plot[1/] heavy
	1966 (Katahdin cultivar)[2/]	
Scab-free:		
Semesan Bel WS dip, 1 lb/7.5 gal	0.03 a	0.00
Scabby:		
Not treated	7.47 c	0.88
Metiram 7% dust 1 lb/cwt	2.61 b	0.32
Captan 7.5% dust 1 lb/cwt	4.30 b	0.17
Captan 5.0% dust 1 lb/cwt	7.05 c	0.72
	1971 (Katahdin cultivar)[3/]	
Scab-free:		
Mancozeb 8% dust 1 lb/cwt	0.0 a	-0.1 a
Scabby:		
Not treated	8.9 d	11.8 b
Mancozeb 8% dust 1 lb/cwt	2.3 ab	0.6 a
Metiram 8% dust 1 lb/cwt	5.4 bc	3.0 a
Metiram 7% dust 1 lb/cwt	6.9 cd	2.0 a

1/ Average of five 10-ft plots; light = tubers with one lesion to 20% of surface area covered by scab lesions, heavy = tubers with 20% or more surface area covered by scab lesions. Negative values resulted from covariance analysis to adjust for yield differences. Small letters indicate groupings of treatments not significantly different at the 5% level.

2/ Manzer, F. E. and D. Merriam 1967.

3/ Manzer, F.E., D. C. Merriam and R. L. Alexander 1972.

Table 9. Results of treating potato seedpieces for the control of scab on Long Island, New York, 1975.

Type of seed and fungicidal treatment	% stand	Yield cwt/A 2/	% scabby tubers	Scab index: All tubers	Scab index: Scabby tubers
Scab-free:					
None	94 a	326 a	3.6 ab	1.85 abc	5.8 ab
Mancozeb 8% dust	95 a	398 b	0.4 a	0.02 a	2.8 a
Scabby:					
None	88 a	307 a	15.0 d	3.04 c	20.0 c
Captan 7.5% dust	99 a	302 a	4.5 bc	0.56 ab	12.1 bc
Mancozeb 6% dust	96 a	305 a	6.5 bcd	1.02 abc	14.8 bc
Mancozeb 8% dust	95 a	319 a	4.3 abc	0.69 ab	14.8 bc
Metiram 7% dust	96 a	331 a	6.6 bcd	1.04 abc	15.0 bc

1/ Tests conducted using the 'Katahdin' cultivar. Small letters indicate Duncan's multiple range groupings of treatments that do not differ significantly at the 5% level. Cetas 1976d.

2/ Two-inch minimum sized tubers.

Table 10. EBDC fungicides and registered alternatives on potatoes.

Fungicide	Common formulations, general use patterns and approximate cost of formulation.
EBDC's	
Mancozeb:	8% dust, most commonly used seedpiece treatment, \$23.00/100 lb.
	80% wettable powder, most commonly used fungicide for late and early blight control, \$1.62/lb.
Maneb:	80% wettable powder, use as foliar spray declining, cost about same as mancozeb.
Zineb:	Limited use both as seedpiece treatment and as foliar spray, not as effective as maneb or mancozeb.
Metiram:	7% dust, limited use as seedpiece treatment, cost about same as 8% mancozeb, reports of phytotoxicity with some formulations.
	80% wettable powder, limited use as foliar spray for late and early blight, cost about same as 80% mancozeb.
Captan:	5-10% dust, the major alternative for EBDC's as seedpiece treatment, dermal irritation to humans has been reported, \$26.00/100 lb for 7.5% dust.
Thiabendazole	45% flowable (registered for seed potatoes going into storage) presently minor usage but very effective against Fusarium seedpiece decay and potentially a major alternative (\$75.00/gal 45% F).

Table 10 (continued)

Fungicide	Common formulations, general use patterns and approximate cost of formulation.
Chlorothalonil:	6 lb active ingredient/gal flowable; most widely used alternative for foliar blight sprays ($28.00/gal GF).
Captafol	4 lb active ingredient/gal flowable, a widely used major alternative for foliar blight sprays; dermal irritation in humans has been reported ($10/gal 4F).
Triphenyltin hydroxide	48% wettable powder; a limited use alternative as foliar blight spray; not generally as effective as major alternatives, very narrow margin of safety between effective late blight control and phytotocity, used occasionally in combination with mancozeb for late blight control. ($15/30 oz, 48% WP).
Anilazine	50% wettable powder; a very limited use alternative as foliar spray for early blight but not as effective as major alternatives, ineffective against late blight. ($3.00/lb, 50% WP)
Copper formulations:	Usually basic, 56% Cu not used since advent of EBDC's; not as effective as major alternatives; phytotoxic effects; difficult to apply.

Table 11. EBDC's and Viable Alternatives, recommended rates and approximate costs of treatment.

Treatment	Rate Active ingredient/acre	Cost per lb active ingredient	Cost active ingredient per acre treatment
Foliar:			
EBDC's (as mancozebs) 80% wettable powder	1.6 lb	1.90	3.00
Captafol 4 lb active/gal flowable	1.5	2.50	3.80
Chlorothalonil 6 lb active/gal flowable	1.125	4.70	5.30
Seedpiece treatment:	Active ingredient per 100 lb seed		
EBDC's (as mancozebs) 8% dust	.08 lb	1.90	3.00
Captan 7.5% dust	.075 lb	1.90	2.85

Table 12 Estimated* usage of EBDC's on potatoes in the U.S. in 1976

	Acreage Exposed	Acreage Treated	Average Frequency	% Treated acreage on which EBDC's used	Volume EBDC's (active ingredient)
Late and/or early blight foliar spray	660,000	599,000	6.1 x	65	3.8×10^6 lb
Early blight foliar spray	714,000	557,000	2.5 x	60	1.3×10^6 lb
Seedpiece treatment	1,374,100	1,078,000	1 x	65	1.1×10^6 lb
Total actual EBDC usage:					6.2×10^6 lb EBDC

*Estimates based on survey of potato specialists and fungicide suppliers throughout the U.S.

TABLE 13. Comparison of General Characteristics of EBDC's with Viable Alternatives on Potatoes

Fungicide	Year Introduced	Phytotoxicity (Potato)	Acute Toxicity	Pathogen Resistance (Potato)	Integrated Pest Management Programs (Potato)
EBDC's					
Mancozeb	1961	none	7,500 mg/kg slight skin irritant	none	Compatible most insecticides including oil sprays.
Metiram	1958	none	6,200 mg/kg slight skin irritant		Broad spectrum action against fungi except powdery mildew protectant. Short residue life.
Zineb	1943	none	5,200 mg/kg slight skin irritant		
Maneb	1950	none	6,700 mg/kg slight skin irritant		
Captan	1949	none	9,000 mg/kg moderate skin irritant	none	Compatible most insecticides except oil sprays. Broad spectrum action. Protectant.
Captafol	1961	none	6,200 mg/kg	none	Compatible most insecticides. Broad spectrum action except powdery mildew. Protectant. Longer residual activity.
Chlorothalonil	1964	none	10,000 mg/kg skin irritant allergenic response	none	Compatible most insecticides including oil sprays. Broad spectrum action includes powdery mildew. Protectant-eradicant. Longer residual activity.

[1]Some formulations as seedpiece dust were phytotoxic. It has not been established whether the metiram or some other ingredient was the cause.

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MUSHROOMS

Efficacy of Zineb as a Fungicide

Because it is a fungus itself, the mushroom is particularly susceptible to fungal diseases that thrive in the environmental conditions the mushroom depends on. New disease threats arise to meet changes in cultural practices brought about to resist existing threats or to increase productivity. One such crisis rose in the 1940's just prior to the introduction of zineb in 1950.

By the fall of 1947, the situation was becoming alarming. Dactylium mildew, Mycogone, and Verticillium spot were so prevalent that even in the first break (harvest) nearly half the mushrooms were spotted or diseased and by the end of the third break only an occasional mushroom escaped infection. The only reasonable solution appeared to be the discovery of a fungicide that could be applied to the beds to kill the pathogens without injuring the mushrooms.[1].

The worst of these diseases was, and still is, Verticillium malthousei (dry bubble disease),U(2) for which zineb is the only effective defense. Zineb is also effective against other fungal pathogens such as Dactylium (mildew), Mycogone (wet bubble), and Trichoderma (green mold),[1] as well as at least one viral infection (Lafrance disease).

Sinden (3) has provided a complete overview of mushroom cultivation and of pathogens and weed-molds affecting the culture. His description of the pathogen Verticillium malthousei follows:

> Verticillium malthousei Ware causes a serious and widespread disease of the sporophores, perhaps the most destructive, and certainly the most ubiquitous of all pathogens of the mushroom. It is endemic on nearly all farms.... Infection of young mushrooms produces small, deformed, undifferentiated, non-necrotic spheres, called dry bubbles, with a dry surface covered with a dusty gray layer of conidia. Later infections on the surface of the large sporophores develop into localized, brown, depressed, necrotic spots also soon covered with the fine grayish layer of spores....
>
> Intensive production in air-conditioned rooms on trays, where six to seven crops per year are grown, in contrast to three or at most four crops on a shelf-bed farm, necessitates a high relative humidity of 90-95% and a temperature of 59-63^{O}F. These are exactly the conditions most conductive to dissemination, inoculation, incubation, and infection of Verticillium malthousei. This pathogen, transmitted primarily by living agents such as pickers and parasitic flies, to which the adhesive spores cling, and disseminated secondarily from primary infections

by water droplets splashed during watering of the beds ..., is difficult to control without resorting to chemical eradicants or protectants...

Since ecological control of Verticillium spot by reduction of the temperature and/or humidity is usually impractical, a selective fungicide is an imperative. One of the earliest fungicides assayed was Bordeaux mixture but it causes injury to the mushroom mycelium so that any mushrooms on the bed at the time of application are made unsalable. In contrast, metal salts of ethylenebisdithiocarbamate specifically target certain fungi since toxicity depends on the presence in a fungus of an enzyme mechanism for reducing the sulfur in the thiocarbamate to H_2S (1). Experience indicates that specificity for Verticillium vs. mushrooms is not total but that the sensitivity difference is sufficient to provide efficient and manageable control.

Some idea of the potential losses without effective control of Verticillium and other fungi can be obtained by comparing production records from early periods with present production. A 1948 reference showed typical mushroom production rates of 1-1/2 lb/sq. ft./filling, (4) which is only about half of present rates. (A "filling" is one use of a given bed area.) Much of the increase since then may be attributable to improvements through other pesticides as well as fertilizers and other cultural innovations, so quantitative losses now from a zineb cutoff would be unlikely to exceed 50%. However, qualitative losses would also have to be considered.

Early experiments investigating potential control agents for Verticillium compared Bordeaux mixture with the ferric (Fermate or ferbam) and zinc (Zerlate or ziram) salts of dimethyl dithiocarbamate. It was shown that Bordeaux mixture gave no better control than the checks (1).

Additional experiments showed that both of these dithiocarbamate fungicides provided higher yields as well as higher percentages of healthy mushrooms, and that the newer EBDC formula, Parzate (or zineb), was superior to both of them. The data from these tests (shown in Figure 1) indicate the untreated trays yielded 14.7 lbs/tray with 54.8% disease incidence, while the trays treated with Parzate (i.e., zineb) produced 16.6 lb/tray with a 31.1% disease incidence. These results demonstrated a zineb efficacy of 12$ more mushrooms with a 23% lower disease incidence. Another experiment in which zineb concentrations were varied showed an average increase of 16% in yield and 20% in mushroom size relative to the check plots (1).

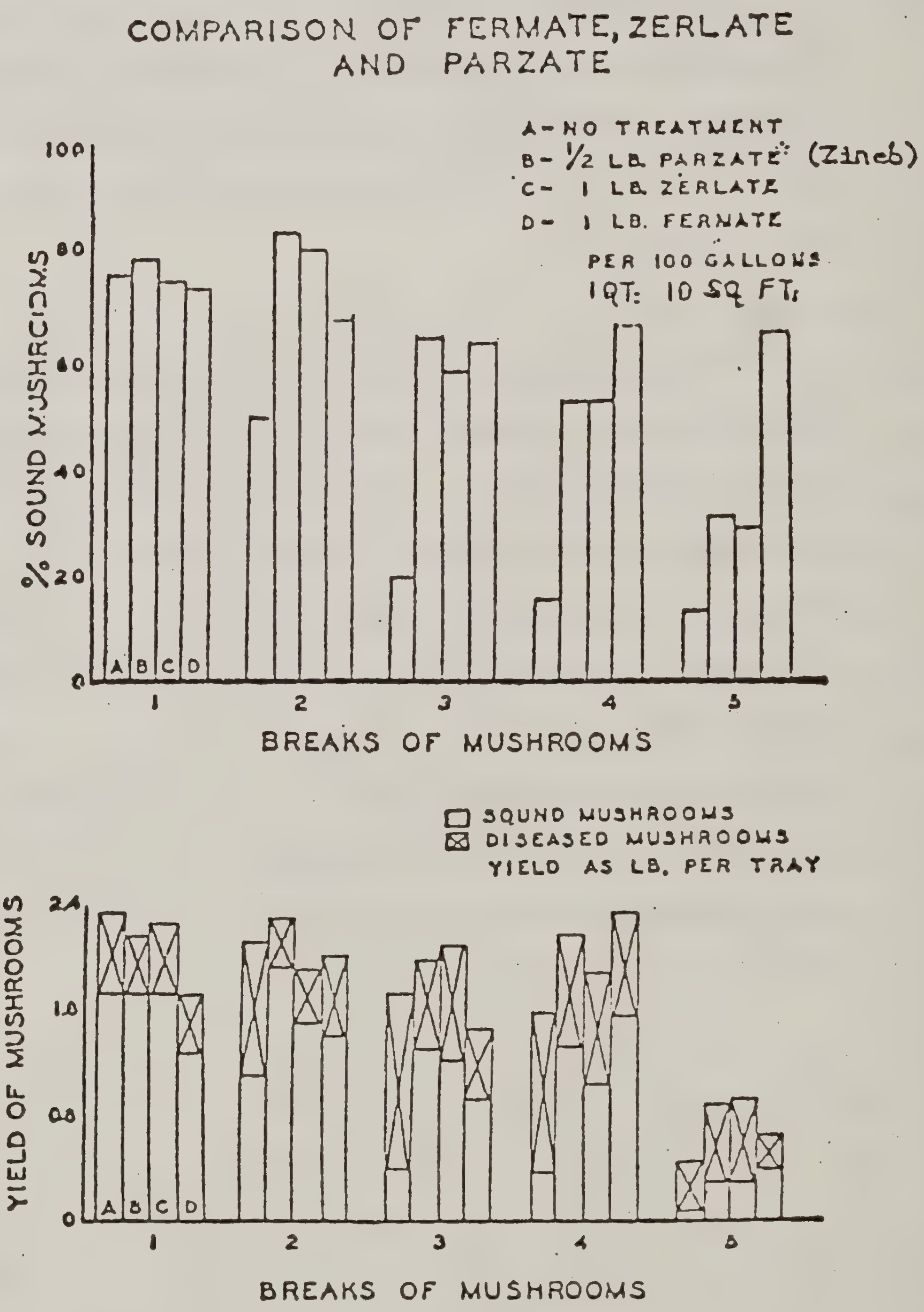

Figure 1 (Fig. 3, Ref. 1)

Dusting with zineb, as opposed to spraying, was subsequently established as the preferred mode of application. Table I presents data on a comparatively recent series of experiments designed to compare spray dosages and times of applications with dusting. The dust treatment generally yielded slightly lower than the other treatments (including the check) but was consistently superior in controlling disease.

Table II presents some results of more recent tests comparing pathogen control measures. By chance the Verticillium spot in these three tests was so heavy that without zineb virtually no salable mushrooms would have been harvested. With zineb the spot was brought into tolerable limits with reduction of about 15% in the number of spotted mushrooms in two tests, and of almost 85% in the third test. Yields were increased with zineb by 5% in two of the tests and by 0% in the third.

Table III (which incidentally shows the overwhelming effects of Verticillium spores deliberately added to the mushroom beds at various times during production) indicates in the two checks that the plot dusted with zineb produced 13% more mushrooms and had 18% lower incidence of disease than the uninoculated plot. Since these results are intermediate among the various test results and they are from a well documented and relatively recent test, they will be considered as the expected efficacy from the use of zineb.

Efficacy of Alternatives

There are no presently known alternatives to zineb in mushroom culture. At one time benomyl was regarded as a very promising alternative but tolerance of Verticillium to benomyl developed very rapidly. "Tolerance...often has occurred at commercial mushroom farms in as little as 9 months or less of continued benomyl usage" (6). The rapid establishment of tolerance to benomyl makes the lengthy history of use of zineb truly remarkable and the likelihood of development of a new alternative remote.

Cythion and methoxychlor have been cited as alternatives to zineb, presumably on the basis that controlling fly population will control dissemination of Verticillium spores. Malathion is presently used at many farms in conjunction with zineb as part of the total pest and pathogen control program. As already noted, however, flies are not the only mode of dissemination of Verticillium and insecticides cannot therefore be regarded as effective alternatives to zineb.

Use of ecological controls by such methods as reduction of temperature and humidity are also impractical because these environmental conditions are the very ones that are most crucial to favorable development of the mushroom.

TABLE I

Zineb Spray vs. Dust

Treatment[a]	Dosage	Yield lbs/sq ft	Bubble/tray[b]	After 35 day %Soot[b]
2 lb. Zineb	single	2.17	9.5	4.21
2 lb. Zineb	multiple	2.20	12.8	6.47
8 lb. Zineb	single	2.16	8.5	4.49
8 lb. Zineb	multiple	2.21	7.8	5.98
16 lb. Zineb	single	2.20	9.9	4.94
Check (no zineb)		2.16	27.6	9.06
Zineb dust		2.10	0.6	0.33

(a)Treatments lbs/100 gal. applied day after casing for single dosage. Multiple dosages applied day after casing and after normal watering when pins had formed and between breaks. Multiple dosages ranged 7 to 9.

Dust applied 3 times/week.

(b)Average 6 tests.

Source: Butler County Mushroom Farm, Inc., PA.

TABLE II

Zineb Dust vs. Verticillium

Treatment	lb/sq ft	lb/lb d wt	Bubble/tray	% Spot[a]
Test 1				
Check[b]	2.49	0.58	3/5	18.9
Zineb dust[c]	2.35	0.61	3/5	3.5
Test 2				
Check[b]	2.38	0.54	22/5	33.3
Zineb dust[b]	2.55	0.58	0/5	19.8
Test 3				
Check[b]	2.35	0.56	12/5	88.6
Zineb dust[b]	2.35	0.56	9/5	3.9

[a]Spot count started 35 days after casting.

[b]60 lbs. compost/tray.

[c]55 lbs. compost/tray.

Source: Butler County Mushroom Farm, Inc., PA.

TABLE III

Effect of Verticillium malthousei inoculum on mushroom yield, Verticillium bubble and spot incidence.

Treatment[a] (Time inoculated)	Yield (lb/ft)	Verticillium bubbles/5 ft tray	% Verticillium spotted mushrooms of total picked
Check - noninoculated[b]	2.49	182	21
Casing	1.09	823	64
7 days	1.13	966	66
14 days	1.00	1021	74
21 days	1.67	518	59
28 days	2.30	283	27
Check - zineb dusted[c]	2.87	12	3

[a]Each treatment had five trays (5 ft^2 x 6 inches deep) per test, repeated three times for a total of 15 trays per treatment.

[b]Noninoculated check refers to the check not inoculated with Verticillium spores. The other treatments except the zineb dust check were inoculated at the indicated times by atomizing the trays with 5000 Verticillium malthousei spores/cc water.

[c]The zineb dusted check was grown in a small room separate from the other treatments, dusted three times per week with 15% zineb and was not inoculated with Verticillium. zineb = zinc ethylenebis-(dithiocarbamate)

(Table 2. Ref. 5)

FRUIT

Eastern Apples.

Current use patterns of EBDC's and alternatives

Forty-three of 49 eastern tree and small fruit pathologists responded to a letter inviting them to submit information on EBDC fungicide usage on fruit crops in their states and to evaluate advantages and disadvantages of alternative materials (Table 1). From the responses to this survey one can detect three typical general use patterns of EBDC's on apples in the East.

In the northern states (167,000 acres, approx. annual production 1.8 billion pounds, Table 2), apple scab is the major disease. EBDC's are used along with captan as alternate materials for benomyl and dodine in areas where resistance to these compounds has occurred in the apple scab organism (*Venturia* inaequalis) (Gilpatrick, Jones, Klos, McGee, 1977). Aerial application programs in Vermont have achieved control of scab and the rust diseases at reduced rates using combinations of mancozeb or metiram with benomyl (Gotlieb, 1977). EBDC's are also used for control of the minor diseases, sooty blotch and fly speck.

In the mid-Atlantic region (95,000 acres, approx. annual production 1.2 billion pounds, Table 1) the disease spectrum includes scab,

powdery mildew, rusts, and fruit rots or "summer diseases." EBDC's are widely used because of economical broad spectrum control, acceptable fruit finish, compatibility with dinocap for powdery mildew control, and compatibility with most commonly used insecticides. Dikar (a formulation of mancozeb and dinocap) and other EBDC's are well suited to integrated mite control programs because of nontoxicity to the beetle predator, Stethorus punctum (Bode, Petersen, Springer, 1977). Use of zineb for late season disease control can eliminate the need for an additional application of an alternate material which has weaker weathering properties (Hickey, Lewis, 1977).

The EBDC usage pattern of the lower mid-western states (Ohio Missouri, 38,000 acres, approx. annual production 340 million lb., Table 1) is represented by characteristrics of Northern and mid-Atlantic regions including broad spectrum disease control, utility in integrated mite control programs, and tank mixtures with benomyl to reduce the threat of benomyl-resistant apple scab (Pecknold, Ries, Spotts, Steiner, Stuckey, 1977).

Fruit rots, scab, rust, and powdery mildew are the major apple diseases in the southeastern states (34,000 acres, 342 million lb annual production, Table 1). The major disease problem is fruit rots; also scab, rust, and powdery mildew. In some areas EBDC's are the only presently available materials capable of adequately controlling the fruit rots under the warm, humid weather conditions which are common during the fruit ripening period in the Southeast (Clayton,

McGlohon, Zehr, 1977). The problem of benomyl resistant apple scab is apparent in one area of this region (Sutton, 1977).

Although these disease and use patterns are generally typical of these regions, local weather factors such as rainfall and temperature can quickly alter the disease complex to favor an epiphytotic by one fungal organism and reduce the threat from another organism. In many areas the major disease problem will vary from year to year depending on the prevailing weather conditions during the particular growing season.

The development of the diseases for which the EBDC fungicides are registered is generally favored by wet periods long enough to allow fungal spores adequate time to germinate and infect susceptible plant tissues. Control of orchard diseases with EBDC fungicides is based upon the maintenance of a protective fungicide residue on the plant surface to prevent the germination of spores and subsequent infection during wet periods. Because heavy rains will reduce the fungicide residue somewhat, application frequency is determined to some extent by the frequency and extent of rainfall and by the amount of plant growth since the last application. The advantage of the EBDC fungicides and disadvantages of alternate materials as reported by eastern fruit pathologists will be discussed in greater detail later in this chapter.

Use survey data from three specific areas indicate grower preference and need for EBDC fungicides in apple disease control programs.

Extension personnel of the University of Illinois survey orchards at harvest annually for fruit quality and insect control programs (Ries, 1977). Four year's sampling data (1973-1976) show that 41% of all fungicide applications involved EBDC materials, including Dikar, Polyram and zineb (Table 3). The only alternative compound used for rust control was ferbam, used a total of 3 times or 0.2%. A grower preference for the Dikar formulation as the means of applying dinocap for powdery mildew control is evidenced by the fact that dinocap was applied only once separate from the 245 Dikar applications.

Similar usage patterns were also noted in North Carolina where the Apple Pest Management Project, 1976, summarized grower spray schedules for 48 randomly selected orchard blocks totalling 400 acres directly representing about half of the apple acreage in the state (Sutton, 1977). Eighty-three percent of the sampled acreage received at least one EBDC application (Table 4). Carbamate fungicides represented 37.8 of the total of 820 applications, and 82% of the carbamate materials were EBDC's. Dinocap was applied as the Dikar formulation in 92.5% of all applications involving dinocap.

In Northern Virginia, a 1977 survey of grower consultants, distributor sales people and growers was estimated to include 75% of all fruit fungicides used in northern and central Virginia, West Virginia, and Maryland (Yoder, unpublished). By weight of formulated material carbamate fungicides represented 52% of all fruit fungicides. Ninety-one percent of all carbamates were EBDC's. Dikar represented 96% of all dinocap used.

In most geographic regions EBDC's are applied at rates of one to two pounds formulated material per 100 gallons of water as a dilute tank mix to be applied at 300-400 gallons per acre of large apple trees, or at an appropriate rate per acre when applied as a concentrate spray increasing the concentration of the material in the spray tank, but reducing the amount of water applied to less than 300 gallons per acre. In practice, much orchard spraying is accomplished with 100 gallons of water per acre or less, and the amount of fungicide applied per acre may be reduced by as much as 25% because of more efficient deposition on the plant surface due to reduced run-off at lower gallonages per acre (Lewis and Hickey, 1972). The actual rate may vary from four to eight pounds of formulated material per acre depending on the size of the trees, the density of the orchard planting, the degree of disease potential, and the method of application.

The amount of a fungicide used per application is also frequently reduced when combined with another fungicide for control of one disease or a complex of diseases. For example, tank mixes of EBDC's with benomyl for reducing the threat of benomyl-resistant fungi are registered at the following rates per 100 gallons: Benlate + Polyram, 2 oz + 1 lb; Benlate + Dithane M-45, 2-3 oz + 12 oz; Benlate + Manzate 200, 2-3 oz + 12 oz. Recommended rates for these materials when applied separately rather than as tank mixes are: Benlate, 4-6 oz; Polyram, 2 lb; Dithane M-45 and Manzate 200, 1 - 2 lb. Zineb 1 lb + Captan 1 lb/100 gal is a common recommendation for late summer disease control in many areas of the East. One application of this combination

can replace the two applications required for similar control by captan at 2 lb/100 gal. (Lewis & Hickey, 1977; Steiner et al. 1978).

The frequency of application of EBDC's varies from 7 to 14 days in the early season, with longer intervals in late season. Intervals between sprays may be lengthened or shortened depending on prevailing weather conditions.

Registered uses and potential crop losses

The major registered uses of EBDC's and the potential crop losses for apples in the East are listed in Table 5. Several minor apple uses are also registered for one or more of the EBDC's. The potential losses to major diseases indicated represent estimates of maximum losses without any control measures based on observations and infection data for disease control experiments. The lack of all control measures would allow some diseases to build up very rapidly in some areas and less rapidly in others depending on weather conditions following the cessation of fungicide control. Likewise, an entire production region would likely realize a gradual cumulative increase in disease incidence following the adoption of a less effective program due to a greater carryover of inoculum from season to season (Szkolnik, 1977).

Besides prevailing weather conditions, another factor which affects disease incidence in the absence of fungicides, or in the presence of a weak fungicide, is varietal susceptibility. Most

present commercial apple cultivars are sustible to scab. "McIntosh" is particularly susceptible. In many areas the complete loss of a season's crop is possible. A tree may be so severely affected that the number of fruit in the following season is greatly reduced. Most of the cultivars are susceptible to one or more of the fruit rots. The Stayman cultivar is particularly susceptible to brown rot because of the tendency for its skin to crack under physiological stress allowing the fungus a point of entry.

Efficacy and availability of EBDC's and alternatives

The effectiveness of a fungicide against the most prominent pathogens in the disease spectrum is the major consideration for its use. The general advantages of the EBDC fungicides over the possible alternatives as described by fruit pathologists are outlined in Table 6. General preference for these materials seems to be based on their economical broad spectrum control, their adaptation to integrated pest management programs, and their acceptable effect on fruit finish. The major diseases on which EBDC's exert outstanding control are the rusts black rot, white rot, bitter rot, sooty blotch, and fly speck. The EBDC's are slightly less effective on apple scab than some other fungicides and are not effective on powdery mildew. Other advantages of EBDC's include the flexibility in disease control programs provided by their compatibility with most fungicides, and their suitability in combination with benomyl for control of benomyl resistant strains of fungi, such as the apple scab organism.

Some beneficial physiological side effects can be achieved with EBDC's. Zineb, mancozeb, and metiram have been recommended for the correction of zinc deficiency (Barrat, 1977; Bates et al, 1977). More recently EBDC's have shown promise of correcting necrotic leaf blotch, an apparent physiological disorder of the Golden Delicious cultivar (Drake, Hickey, Lewis, Springer, 1977).

Because of the wide range of activity of the EBDC's, a number of fungicides must be considered as possible alternatives. Of the group of eight materials listed in Table 5, only ferbam and thiram cover the entire range of disease control evident in EBDC's. These two materials each have some serious disadvantages as noted in Table 7. One serious consideration would be the question of their availability for rust control, and what their price would be in the event of a temporary or long-term shortage with declining EBDC sales competition. A similar situation could exist with captan and folpet which would currently be the most likely replacements for EBDC's in the summer control of the fruit rot diseases.

Benomyl, captafol, dichlone, and dodine would be considered as EBDC replacements mainly for the control of apple scab. Captafol and dichlone have excellent activity against the apple scab fungus, but are seriously limited by toxicity to the plant. Benomyl and dodine are also excellent apple scab materials, but extensive use in areas where scab is an annual problem has led to the development of resistant strains of the fungus (Jones, 1976), and this seriously limits their reliability when used without the benefit of another

fungicide with a different mode of action such as EBDC's or captan. Other materials not listed in Table 5, but which are also registered for apple include glyodin, lime sulfur and sulfur. Glyodin is regarded chiefly as a surfactant and a weak scab protectant fungicide. Lime sulfur has strong scab activity, but is phytotoxic. Sulfur is used more for control of powdery mildew than for apple scab due to its phytotoxicity at rates high enough to give adequate scab control.

The foregoing discussion of disadvantages of alternate materials is not intended to obscure the fact that by evidence of their inclusion and discussion in most eastern fruit spray publications, the EBDC's and all of the alternatives are recognized as having some utility. In rather complex systems of the economic mangement of a spectrum of fruit pathogens and insects to produce a high quality product, each fungicide has found its own rightful niche. The exclusion of one group of compounds could lead to increased use of other materials less effective. The end result would be reduced yield and quality, increased total active ingredient required, increased likelihood of pathogen resistance, and increased risk of exposure to all remaining groups of materials.

An analysis of the benefits of the EBDC fungicides and their alternatives is not complete without noting that many of the most useful alternatives are either directly or indirectly involved with some review processes related to RPAR's.

Phytotoxicity

A differential varietal response is also evident in the realm of injury of fruit and foliage by spray materials. Some fungicides such as dichlone, folpet and captafol may be generally injurious if applied at the wrong growth stage; others may be more harmful to one cultivar than another. Frequently, cold or warm temperatures and coincidental application of another pesticide may be factors involved in the development of symptoms of phytotoxicity. Mixtures of compounds may synergize to produce injury or to increase the safety of each depending on their nature. Some examples of susceptibility to chemical injury are: Golden Delicious (ferbam, dodine, sulfur, benomyl); Red Delicious (captan, dodine + sulfur, ferbam); Stayman (captan + sulfur, ferbam).

Phytotoxicity problems are compounded by the importance of the russet-susceptible Golden Delicious cultivar as a pollinator. Because of its wide use as a pollinator, it is often interplanted in the row with another cultivar or in rows alternated with rows of other cultivars. In either case, it is generally impractical to avoid spraying certain trees within the same orchard with a given material due to phytotoxicity problems.

No serious phytotoxicity problems have been associated with mancozeb, metiram, zineb or thiram, with the exception of reduced fruit set due to the dinocap component of Dikar (Steiner, 1977).

Potential for pathogen resistance

In recent years the problem of the development of fungal resistance to fungicides has caused increasing concern (Jones, 1976). Among fruit fungicides, benomyl and dodine have been particularly susceptible to erosion of effectiveness on apple scab due to this problem. The problem has generally appeared first under severe disease conditions where dodine has been used exclusively for about ten years and where benomyl has been used for about three years. Because of their different chemical modes of action and their compatibility with benomyl; mancozeb, metiram, and captan have been registered for inclusion with benomyl in the spray tank to delay the onset of tolerant strains and to reduce the threat of their appearance (Jones and Ehret, 1977). In addition, many eastern spray bulletins encourage the use of other materials throughout the entire season (Bates *et al*, 1977; Flore *et al*, 1976; Oberly *et al*, 1977; Rock *et al*, 1977).

With a comparatively long history of exclusive usage on eastern fruit crops, there has been no evidence of development of resistance to any EBDC fungicides.

Integrated pest management

An outstanding benefit of the EBDC's in the East is their adaptability to the integrated mite control programs which have become popular as a means of reducing the total cost and amount of pesticides

needed per acre per year. The EBDC's are non-toxic to the mite predators, the Black Lady Beetle, Stethorus punctum in the midAtlantic regions and the mite predator Amblysieus fallacis in the Midwest (Rock et al, 1977; Tetrault et al, 1977; Williams et al, 1976). Some of the popularity of the Dikar formulation of mancozeb and dinocap results from its suppression of the plant feeding mites while permitting survival of the mite predators, and a significant cost savings by purchasing the package mix formulation rather than by using the same total active ingredients of mancozeb and dinocap in separate packages.

In Pennsylvania the use of a "Reduced Pesticide Spray Program for Apples," in which Dikar is one of several important features, was estimated in 1971 to reduce total pesticides applied 45% for a savings of $58 per acre (Lewis and Hickey, 1972).

In Missouri (Steiner, 1977) a combination of mancozeb + benomyl is estimated to save two or three miticide applications per season in comparison to a standard captan or metiram fungicide program. Compared to several other programs, this program also used the lowest total amount of active ingredients per acre per year.

General cost considerations

Throughout the East most of the commercial fruit fungicides are generally competitive in price considering their spectrum of disease control, use rate, longevity on the plant, etc. A difference has been

noted, however, between the price of Dikar and the cost of mancozeb and dincap if purchased as separate formulations. As of February 1, 1978, at typical medium to large grower purchase volumes, Dikar (72% mancozeb, 4.7% dinocap) costs $1.34/lb, Dithane M-45 (80% mancozeb) costs $1.35, and Karathane WD (19.5% dinocap) costs $1.95 (Labbee, 1978). The same quantity of active ingredients available for $1.34 in one pound of Dikar will cost $1.68 if purchased separately. Thus, a savings of 34 cents is realized for each pound of Dikar sold in the country.

Basis for economic analysis

An analysis of the economic benefits of EBDC fungicides on eastern apple production is outlined in another section of this document. Presented here are observations and assumptions which servere as the basis for this analysis.

The economic analysis focuses on two major production regions and their EBDC usage patterns: the Southeast and the mid-Atlantic and lower mid-western states. The analysis is based on typical usage patterns and the production and acreage in these regions. It is recognized that all growers in the region may not be following the typical usage pattern because of different disease conditions. It is likely, however, that disease control practices by many growers in states bordering these regions would also fit the EBDC usage pattern for these regions.

The fruit rots are the most serious disease problem in the Southeast with bitter rot (<u>Glomerella cingulata</u>) being one of the most difficult to control under severe conditions. Preventive treatment prior to infection with as many as eleven or more applications controls this and other diseases. EBDC's are preferred for control of bitter rot in North Carolina (Rock <u>et al</u>, 1977) with folpet (Phaltan) being the next best alternative. Under North Carolina test conditions in 1976 Dikar 2 lb/100 gal permitted only a 2% loss of fruit, followed by Phaltan 2 lb/100 gal (30% loss) and captan 2 lb/100 gal (61% loss) (Clayton and Sutton, 1977). The Phaltan-treated trees also suffered foliar chemical injury. In 1977 typical grower prices were $1.27 per lb for Dikar and $1.35 per lb of Phaltan. Application volumes are 400 gal per acre with the fungicide concentrations used in the test, or the same amount of active material per acre where reduced gallonages are applied to large trees. Grower prices for high quality Golden Delicious have ranged from $7.00/100 lb in 1975 to $12.00/100 lb in 1977.

This test illustrates the destructive nature of bitter rot and the potential difficulty in its control without EBDC fungicides. The 28% loss in rotted Phaltan-treated fruit probably would have been more than a 28% loss in value because infection data were taken three weeks before harvest. Under commercial conditions additional sorting costs would likely be accrued to remove more rotted fruit after harvest. The disease may not be this severe in every southeastern orchard every year, but loss of the most effective materials would likely result in an overall increase in rot incidence under adverse weather conditions.

Economic analysis of loss of the benefits of EBDC's in the mid-Atlantic and lower mid-West is based on differences in disease control and pest management:

a) cost of at least one additional miticide application with the loss of the integrated pest management benefits of EBDC's.

b) cost of an additional application of an alternate material due to the loss of zineb in the late season sprays.

c) additional costs for alternate disease control materials in early and mid-season sprays.

Prices for alternate materials are typical grower prices for 1977 in Northern Virginia. Biological reasons for the required spray schedule alterations are based on spray bulletins and comments by eastern fruit pathologists. Cost of application/acre is approximately $2.00 (Lewis and Hickey, 1972, from a range of $1.41-$2.32). The following points refer respectively to the items listed above for the aforementioned regions:

a) The EBDC fungicides are compatible to integrated mite control programs as discussed earlier. Their loss in the spray program we estimate would require an additional miticide such as Plictran (Steiner _et al_, 1978) 0.75 lb/A or $9.00/A plus the cost of application. If captan is relied on as the alternate fungicide, possibly more than one additional miticide may be required in some

areas due to its tendency to permit an increase in phytophagous mite populations (Clayton and Sutton, 1976; Lewis and Hickey, 1972).

b) Zineb is widely recommended in late season cover sprays in combination with captan for its longer residual effectiveness on sooty blotch and fly speck diseases which can cause a serious loss in grade of fruit (Lewis and Hickey, 1977). Additional costs over the treated acreage would include 4.5 lb captan/A (Steiner _et al_, 1978) at 95¢/lb plus the cost of application at $2.00/A.

c) Alternate materials for disease control selected from the 1977 Pennsylvania Tree Fruit Production Guide (Tetrault _et al_, 1977) and typical 1977 Virginia prices for formulated materials include: captan, 95¢/lb; thiram, $1.35/lb; dinocap, $2.39/lb; benomyl, $7.30/lb; superior oil, 38¢/qt.

Plums and prunes

Zineb is widely used for control of the black knot disease (_Dibotryon morbosum_) attacking the twigs, branches, and trunks of prune trees (Lewis Hickey, 1959). Eastern plantings total about 8800 acres in Michigan, York, Pennsylvania, Ohio, and Maryland. Benomyl is an effective alternative for zineb (Ritchie, _et al_, 1975), but because of the potential for fungal resistance to benomyl, zineb should be retained and recommended as a tank mix or alternate application with benomyl. No other alternative materials are acceptable

due to phytotoxic potential. As an additional control practice, growers are encouraged to remove wild plum and cherry trees from the vicinity of the orchard and to prune out and destroy overwintering knots from infected trees (Anderson, 1956). This practice is only partially successful, however, because some infections are invisible during the dormant season, and small sporulating knots may be obscured by the foliage while the tree is in active growth. Evidence of the explosive nature of this disease is the fact that three knots left in one tree resulted in over 1100 new infections in a single growing season (Ritchie *et al*, 1975). Without fungicides we estimate that at least 4,000 acres containing approximately 400,000 trees would gradually become infected and would be lost to production.

Grapes

Maneb and mancozeb are critical to about 3000 acres of muscadine grape production in the Southeast. The best alternative, folpet, is less effective than these materials for control of fruit rots, particularly ripe rot (*Glomerella cingulata*), and this acreage would likely be lost to production (Clayton, 1977).

Maneb and mancozeb are also used on approximately 5000 acres of grapes in Ohio (Spotts, 1977) and Missouri (Steiner, 1977) where they are preferred because of superior control of black rot and downy mildew.

Restriction of EBDC's would affect a changing variety picture in New York, because of the move toward the planting of French hybrid grapes. These cultivars are susceptible to downy mildew and would need mancozeb for disease control as evidenced by the heavy EBDC usage on grapes in Europe.

Cranberries

Although some EBDC's are used in cranberry production, they are not applied directly to water in the production operation. In Wisconsin and Oregon the crops are grown and harvested as dry land agriculture. In Massachusetts (Cross, 1977) and New Jersey (Marucci, 1977) fungicides are applied to cranberries only during bloom periods to control fruit rots. The bogs are drained before bloom and are not reflooded until approximately 42 days after fungicide application in New Jersey and 64 days in Massachusetts. All fungicide application is on unflooded land.

Western deciduous tree fruits

In general, EBDC's are used much less extensively on deciduous tree fruits in the West than in the East because wet weather fungi are not as prominent under the dry climatic conditions in the western fruit-growing regions. One important use is noted, however, in Washington and Oregon where EBDC's are applied to pears for control of pear psylla nymphs. These sucking insects are capable of reducing tree vigor by their feeding and give off honeydew which serves as a

substrate for sooty mold fungi which shade the tree. They also transmit the lethal pear decline disease. An estimated 20,000 acres are treated (50% of the total) with zineb at 6-8 lb/A in Oregon (MacSwan, 1978), and mancozeb is used at 9 lb/A on 20,000 acres (55% of the total) of pears in Washington (Covey, 1978). Research in British Columbia demonstrated that mancozeb and Dikar are capable of controlling pear psylla nymphs which had become resistant to numerous conventional insecticides (McMullen, 1966). Mancozeb and Dikar had very little effect on the predaceous insects.

Hops

Another use of EBDC's in the northwest is in the production of hops. Approximately 42,000 pounds of zineb is used on 8500 acres in Idaho and Oregon for control of downy mildew (Pseudoperonospora humili). The alternate materials copper and streptomycin are comparatively ineffective (Paulus, 1978).

Citrus

Approximately 460,000 pounds of zineb is used on Florida citrus (Kahn, 1978) for control of fruit russet and greasy spot (Fisher, 1961). A single application of the material is made at the rate of 8 lb/100 gal of water per acre tank mixed with the summer oil spray applied in June or July. Alternate fungicides include captafol and benomyl.

Other fruit crops

Because of their economical broad spectrum disease control, their common availability, and their safety to plants, EBDC fungicides have been recommended on a wide range of relatively minor tree fruit, small fruit and nut crop diseases. A summary of registrations is listed in Table 2. Several relatively small acreage fruit crops on which EBDC's are used in commercial production in the East include pears, raspberries, and currants. EBDC's are also useful in home fruit production because they control most of the major diseases which would seriously damage the fruit. Their inexpensive broad spectrum control makes them especially useful because they are also adaptable for home vegetable gardens and landscape ornamentals. EBDC's have also been recommended for control of several nut diseases (W. Johnson, 1969).

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TABLE 1. EASTERN APPLE PRODUCTION

Region	Acreage[1]	Avg. Annual Production[2] (million lb.)
Northern		
Maine		68.6
New Hampshire		56.4
Vermont		57.2
Massachusetts	27,299	87.6
Connecticut		39.8
Rhode Island		4.4
New York	66,742	869.8
Michigan	66,157	572.0
Wisconsin	7,028	45.2
Mid-west		
Indiana	5,193	54.8
Illinois	12,000	94.2
Ohio	11,168	113.4
Kentucky	unavailable	14.4
Missouri	8,000	63.3
Mid-Atlantic		
Pennsylvania	34,601	464.0
New Jersey	7,911	115.0
Delaware	unavailable	12.1
Maryland	5,837	69.8
West Virginia	18,000	216.0
Virginia	28,500	344.0
Southeast		
North Carolina	18,500	271.0
South Carolina	2,896	22.4
Georgia	7,000	22.0
Tennessee	unavailable	7.7
Arkansas	unavailable	18.5
TOTAL	approx. 325,000	3703.6

Total Eastern production 3.6 billion pounds, approx. annual value $220 million

Total U. S. production 6.7 billion pounds, approx. annual value $380 million

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[1] Most recent state surveys (1972-1976).

[2] Five year averages (1973-1977), Statistical Reporting Service, USDA.

TABLE 2. EBDC FUNGICIDES REGISTERED FOR CONTROL OF DISEASES OF FRUITS*

Fruit	Disease	Registered EBDC
Apples	Bitter rot	Mancozeb Polyram Zineb
	Black rot	Maneb Polyram Zineb Mancozeb
	Blotch	Zineb
	White rot	Polyram Zineb Maneb
	Brooks spot	Zineb
	Brown rot	Mancozeb Polyram
	Bullseye rot	Maneb
	Cedar apple rust	Mancozeb Maneb Polyram Zineb
	Fire blight	Zineb
	Flyspeck	Mancozeb Maneb Polyram Zineb
	Frogeye leaf spot	Zineb
	Quince rust	Zineb
	Rust	Mancozeb
	Scab	Amobam Mancozeb Maneb Polyram Zineb
	Sooty blotch	Mancozeb Maneb Polyram Zineb

*Based on EPA microfiche label and registration files.

Fruit	Disease	Registered EBDC
Apricots	Brown rot	Maneb
	Green rot (Jacket rot)	Maneb
	Leaf curl	Zineb
	Shot hole	Maneb Zineb
Blackberry	Anthracnose	Zineb
	Leaf rust	Zineb
	Rust	Zineb
	Septoria leaf spot	Zineb
Blueberry	Botrytis blight	Mancozeb
Boysenberry	Anthracnose	Zineb
	Rust	Zineb
	Septoria leaf spot	Zineb
Cherry (ALL)	Leaf spot	Zineb
	Shot hole	Zineb
Citrus (ALL)	Greasy spot	Zineb
Cranberries	Fruit rots	Mancozeb Zineb
	Lophodermium	Maneb
Currant	Leaf spots	Zineb
Dewberry	Cane rust	Zineb
Gooseberry	Leaf spots	Zineb

Fruit	Disease	Registered EBDC
Grapes	Bitter rot	Zineb
	Black rot	Mancozeb Maneb Zineb
	Brown rot	Zineb
	Bunch rot (Botrytis)	Mancozeb Zineb
	Dead-arm	Mancozeb Zineb
	Downy mildew	Mancozeb Zineb
	Ripe rot	Zineb
Kumquat	Greasy spot	Zineb
Lemons	Storage rots	Zineb
Loganberry	Anthracnose	Zineb
	Septoria leaf spot	Zineb
Nectarine	Brown rot	Maneb Zineb
	Coryneum blight (leaf blight, shot hole)	Maneb Zineb
	Leaf curl	Zineb
	Leaf spot	Zineb
	Scab	Zineb
Papaya	Anthracnose	Mancozeb Maneb
	Black spot	Maneb
	Phytophthora fruit rot	Mancozeb

Fruit	Disease	Registered EBDC
Peach	Brown rot	Maneb Zineb
	Leaf curl	Zineb
	Leaf spts	Zineb
	Scab	Zineb Maneb
	Shot hole (blight)	Maneb Zineb
Pear	Bitter rot	Mancozeb
	Black rot	Mancozeb
	Fire blight	Zineb
	Flyspeck	Mancozeb
	Rust	Mancozeb
	Scab	Mancozeb
	Sooty blotch	Mancozeb Zineb
	Pear psylla	Mancozeb
Pineapple	Heart rot	Mancozeb
Plum and prunes	Black knot	Zineb
	Brown rot	Zineb
	Leaf curl	Zineb
	Leaf spots	Zineb
	Scab	Zineb
Raspberry	Anthracnose	Zineb
	Septoria leaf spot	Zineb
Strawberry	Stem rot	Zineb

TABLE 3. Fungicides and the Number of Applications Each Used by Members of the Illinois Quality Apple Club during the Years 1973-1976[1]

Fungicide	Number of Fungicide Spray Applications[2] 1973 (22)[3]	1974 (19)	1975 (25)	1976 (14)	Total	% of Total
Benomyl	3	45	55	29	132	8.6
Captan	39	42	29	40	150	9.7
Captafol	4	4	9	9	26	1.2
Copper chem.	1	1	0	0	2	0.1
Dikar	76	59	104	45	245	15.9
Dinocap	1	0	0	0	1	0.1
Dodine	108	65	69	48	290	18.8
Ferbam	1	2	0	0	3	0.2
Phaltan	33	33	34	22	122	8.9
Polyram	53	68	64	22	207	13.4
Sulfur	74	38	23	28	163	10.6
Zineb	66	29	21	22	138	8.9
Others	0	5	8	11	24	1.6
Total EBDC's	195	156	189	89	629	40.8

[1]Ries, 1977 (Condensed from Transactions of the Illinois State Horticultural Society, 1973-1976).

[2]The number of times the listed fungicides were applied for disease control in the years listed.

[3]Number of growers participating in the survey.

TABLE 4. Fungicide Applications to 48 Orchard Blocks Surveyed by North Carolina Apple Pest Management Project, 1976 (Sutton, 1977)

Fungicide	Total Applications[1]	% of Total Applications
Benomyl	161	19.6
Captan	211	25.7
Dikar	161	9.6
Dinocap	13	1.6
Dodine	17	2.0
Ferbam	33	4.0
Folpet	67	8.2
Kolofog	12	1.5
Lime sulfur	2	0.2
Mancozeb	4	0.5
Maneb	1	0.1
Polyram	70	8.5
Sulfur	25	3.0
Thiram	23	2.8
Zineb	20	2.4
Total EBDC's	256	31.2
Total	820	100.0

[1]The number of times the listed fungicides were applied for disease control.

TABLE 5. Potential Uncontrolled Losses to Major Eastern Apple Diseases in the Absence of Fungicides

Major Registered Uses	Causal Organism	Potential Maximum Loss without treatment (%)[1]	Estimated Area Affected[2] Acreage (thousand)	Estimated Area Affected[2] Production (million lb.)	Reference
Scab	Ventruia inaequalis[3]	100[3]	266	3,000	Klos, Yoder *et al*, 1970
Rusts	Gymnosporangium sp.[3]	75[3]	135	1,500	Anderson, 1956
Black rot	Physalospora obtusa	100[4]	140	1,600	Hickey, 1971
Bitter rot	Glomerella cingulata	100	140	1,600	Clayton & Sutton, 1976a
Botryosphaeria rot	Botryosphaeris ribis	80[4]	140	1,600	Albert, 1974
Sooty blotch	Gloeodes pomigena[5]	100[5]	225	2,500	Clayton & Sutton, 1976a
Fly speck	Microthyriella rubi	100[5]	225	2,500	Clayton & Sutton, 1976a
Brown rot	Monilinia sp.	50	25	253	Yoder, 1977

[1]Based on losses on untreated trees in disease control experiments or observations in local areas.

[2]Acreages and affected production estimated from prevalance of diseases throughtout eastern production regions.

[3]Severe infection one season may reduce yield for two seasons.

[4]Percent fruit loss. Also capable of producing cankers that kill trees.

[5]Percent fruit infected. Some superficially infected fruit may be salvaged for juice.

TABLE 6. ADVANTAGES OF EBDC FUNGICIDES ON APPLES (1)

Broad spectrum disease control
Well adapted to integrated pest management programs
Good cost/benefit ratio
Fair to good effect on fruit finish
Compatible with spray oil
Combination labels with benomyl for control of resistant strains
Add flexibility to disease control programs
Beneficial physiological effects

(1) Based on surveys of eastern fruit pathologists and spray bulletins.

TABLE 7. DISADVANTAGES OF INDIVIDUAL ALTERNATIVE APPLE FUNGICIDES (1)

Benomyl
- doesn't control rust diseases
- not recommended for use alone because of potential for resistance
- registration situation uncertain

Captafol
- early season use for scab only
- phytotoxicity
- dermatitis effects

Captan
- does not control rusts or powdery mildew
- weak control of "summer diseases"
- incompatible with spray oils and sulfur
- cost increase predicted
- registration situation uncertain
- permits increase in mite populations

Dichlone
- injurious to fruit and foliage
- incompatible with spray oils

Dodine
- controls scab only
- resistant strains of *V. inaequalis* in several areas where scab is the most important disease
- reduced fruit quality of Golden Delicious

Ferbam
- phytotoxicity - severe russeting of Golden Delicious
- black residue - should be used with spreader to avoid residue problem
- supply for rust control uncertain
- weak on scab control

Folpet
- does not control rusts or powdery mildew
- cannot be used in early and mid-season due to phytotoxicity
- more expensive
- registration situation uncertain
- supply questionable

Thiram
- generally weaker than EBDC's for control of most diseases
- more expensive
- supply for rust control questionable

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(1) Based on surveys of eastern fruit pathologists and spray bulletins.

Cereal Crops Wheat, Barley, Oats, and Wildrice

The use and distribution of the EBDC fungicides on cereal crops is rather complex because of the movement of the chemicals across state borders, by both growers and distributors. There are two important uses of these fungicides on the cereal crops: 1) Seed treatment, 2) foliage protectant.

Regarding the plant diseases that involve the use of the EBDC fungicides, there are no known threshold levels that may be used to identify the potential crop loss that may be experienced prior to the time that disease control practices may be exercised. These fungicides are protectants; they do not erradicate a disease problem once it is started. In the case of cereal diseases controlled with the EBDC fungicides, the fungi which cause the ensuing disease are so influenced by the micro-environment that potential disease loss is difficult if not impossible to predict before the disease occurs.

Prior to the loss of the alkyl mercury seed treatment chemicals nearly all seed treating was done by commercial seed houses or elevator operators. Now most of the cereal crop seed treatment is done by growers on the farms. Where one commercial operator once treated seed for several hundred growers, now we have a situation where several hundred growers are individually treating their own seed. The on-the-farm equipment for seed treating does not do as efficient a job of treating as was done by the commercial equipment

previously referred to. In addition, the cost of all the extra equipment has greatly increased the expense of the practice.

Seed treatment is the standard practice of using a fungicide coating of the seed to protect the seed from invasion by fungi and bacteria which results in damping off or seedling blight.

There are several fungicides currently registered for use as seed treatment on the cereal grains, wheat, barley, and oats. The most common of these chemicals include, maneb, mancozeb, captan, Teracoat, thiram, Vitavax, and a combination of these materials. Maneb is probably the fungicide used most for the protection of external seedborne fungi and soil-borne fungi. Each of these fungicides has specific uses, directly related to specific microorgnisms.

The use of EBDC fungicides as a seed treatment chemical on the cereal grain crops (wheat, barley, and oats) is mostly confined to the North Central States (Minnesota, North Dakota, South Dakota, and Montana). As a seed treatment, the chemical is applied to the seed as a dust, or slurry depending upon the available equipment. The chemical acts as a barrier or guard against invasion of the seed by soil-borne and seed-borne fungi. These fungi may invade unprotected seed prior to emergence. Seed treatment only protects the actual seed from invasion. Once the seed has emerged, the plant is generally resistant to these fungi. Therefore, seed treatment is very important in the establishment of healthy stands of the cereal grains.

The types of fungicide used as seed treatment will vary throughout the wheat growing areas depending upon the types of soil-borne and seed-borne fungi present. In the winter wheat areas, namely Kansas, Oklahoma, Missouri, and Nebraska, the nature of the fungus flora is such that other fungicides such as Terra-coat®, give better protection. However, at this time this chemical is on the RPAR list for review. In light of this fact, it hardly seems reasonable to consider such a chemical as an alternative.

The spring wheat and Durum wheat growing areas, North Dakota, South Dakota, Montana, and Minnesota account for 17,249,000 acres of wheat, with an average yield of 28 bushels per acre.

The result of 10 years of field tests with the EBDC fungicides as a seed treatment is 4.1 bushels per acre of incresed yield. This 4.1 bushel yield increase resulted from an increased stand of 26.9%. Approximately 1,700,000 acres of spring wheat and Durum wheat are treated with an EBDC fungicide which at 4.1 bushels increase per acre, represents 6,970,000 bushels of wheat currently produced by the wheat farmers at no additional expense of energy.

In the winter wheat areas of Indiana and Kansas more than 1,028,000 acres of wheat are treated with EBDC seed treatments.

In the case of barley, 5,832,000 acres are grown in the North Central states, Minnesota, North Dakota, South Dakota, and Montana.

In the North Central states, about 1.8 million acres are treated with the various EBDC seed treatment fungicides. The 10 years of seed treatment testing referred to above also included barley. The over all average yield increase for the use of seed treatment was 4.1 bushels per acre. The same conditions and needs exist for the use of seed treatment on the barley crop as was expressed for the wheat crop.

In general practice, most of the oat crop is not treated. This condition relates to the cultural practices involving the growing of oats, which for most growers is not a high value crop. In 1976 the yield of the major oat variety (Froker) in southern Minnesota was reduced by 30% from smut because it was not treated.

Historically the value of seed treatment with salt water was discovered when wheat was traded and shipped in wooden ships. Salt water leaking into the ship holds contaminated the wheat seed. If the seed survived this treatment, when it was planted it did not develop smut, a seed-borne disease. Seed treatment chemicals were tested and methods of treatment were developed that provided a very inexpensive and effective protection of the seed. The culminations of this work was the use of the alkyl mercury fungicides, where 1/3 ounce of 3% mercury would effectively treat one bushel of seed. With the loss of registration for the mercury fungicide, we have resorted to using much less effective chemicals at a greater grower cost and which are more difficult to apply. This has resulted in the reduced use of seed treating by growers, resulting in considerable loss of yield. In the early 1960's in North Dakota, about 78% of the cereal grain seed for

sowing was treated. At present about 30% of the cereal crop is treated. The overall effect has been to increase the cost of production.

Application Techniques

Before the loss of the mercurial seed treatment fungicides, most of the seed treatment was done at commercial seed houses with high volume machines that measured and applied the chemical. The seed was then hauled by truck to the field for planting. Prior to the use of these techniques, seed was treated by hand, by the undivided grower, usually resulting in poor or inadequate application. Today, because of the loss of registration of the mercury chemical, about 60% of the seed treating is again done on the farm, with various types of drill box treating apparatus.

The EBDC fungicides are used throughout the world as a foliage protectant fungicide on cereal grain crops. These fungicides are used to protect cereal crops from diseases such as Leaf Rust, Septoria Leaf Blotch, Net Blotch, Spot Blotch & Brown Spot. All of these plant diseases attack and destroy the cereal plant leaves, causing major crop losses. The practice of applying fungicides on a commercial basis is relatively new, since 1962.

The acreage treated often depends upon the amount of crop value. In 1975, Minnesota farmers treated about 1 million acres of cereal crops. In 1976, more than 400,000 acres of winter wheat were treated

in Missouri. Results from 4 years of "on the farm" tests in North Dakota showed an average 28% increased yield. See Tables 3,4,5,6, and 7 for yield response data relating to the value of Maneb-type fungicides as a disease control practice.

The practice of applying fungicides to the cereal grain crops of the United States is a new practice. The average increases in yields are greater for fungicide protection than for the introduction of a new variety. Increased yields reduce production and energy costs to the grower. The EBDC fungicides are necessary for the production on cereal crops. There are no alternative fungicides that can be used for the protection of cereal grains from the various leaf spotting plant diseases. Resistant crop varieties do not exist. This practice is used in Brazil, Argentina, Isreal, and other near eastern countries (Dr. J. [illegible]igo, Cereal Pathologist, FAO).

The Use of Mancozeb on Wildrice

In Minnesota, paddy grown wildrice is subject to several leaf spot diseases. The most important leaf spot disease caused by the fungus Helminthosporium sativum, can completely destroy the crop in some years.

Wildrice in most years has the potential of producing 1500 to 1800 pounds of rice per acre. The above leaf spot disease often reduces such yield by 500 to 600 pounds per acre (Dr. M. F. Kernkamp, Plant Pathologist, University of Minnesota).

The wildrice crop in Minnesota requires 4 applications of fungicide to prevent the above losses. Minnesota may grow as much as 23,000 acres of paddy rice per year. Approximately one half of the crop is treated each year.

In the 1977 growing season, 9354 acres of wildrice were treated with EBDC fungicide to control the leaf spot diseases. Four applications were made, costing $17.00 per acre for the season. Using a minimum of 200 pounds per acre increase over untreated rice, results in an increased income of $183.00 per acre. The wildrice crop has an income valued at harvest of $1.00 to $1.25 per pound. The final retail value varies from $3.50 to $5.50 per pound.

In the case of wildrice, there are no alternative fungicides that can be used to control these leaf spot disease.

TABLE 1

IDENTIFIED USE OF MANEB-TYPE FUNGICIDES
AS CEREAL GRAIN SEED TREATMENT

STATE	AMOUNT IN POUNDS	APPROXIMATE ACREAGE TREATED	PERCENTAGE OF CROP TREATED
Oklahoma	---	---	< 1%
Kansas	158,687	1,157,469	8.5%
Illinois	---	---	< 1%
Missouri	---	---	< 1%
North Dakota	426,150	2,894,800	---
Montana	150,000	1,200,000	---
South Dakota	30,000	240,000	---
Minnesota	150,000	1,200,000	---
Indiana	3,500	14,000	---
Misc.-States	50,000	200,000	---
TOTAL	954,000	6,892,269	---

Rate of application: 2 oz. per bushel of seed average planting rate-1 bushel of seed per acre.

TABLE 2

BENEFIT[1] OF MANEB-TYPE SEED TREATMENT
IN THE NORTH CENTRAL STATE

STATE	YEAR	CROP	TREATED STAND	TREATED YIELD[2]	UNTREATED STAND	UNTREATED YIELD
Montana	'76	S.W.	233	34.6	166	32.0
North Dakota	'76	S.W.	222	23.4	151	22.2
Montana	'76	W.W.	516	30.3	388	25.2
Minnesota	'76	S.W.	291	43.5	267	42.2
South Dakota	'74	S.W.	294	17.5	205	15.0
South Dakota	'74	W.W.	172	22.6	149	19.8
Minnesota	'73	S.W.	248	62.0	161	57.0
North Dakota	'73	Bar.	-	51.2	-	48.5
North Dakota	'67	S.W.	-	25.2	-	21.0

TEN YEAR AVERAGE - 26% increase in stand
4.1 bushels/acre

[1]/Selected examples from 10 years of "on the farm" test.

[2]/Yield in bushels per acre.

TABLE 3

Yields of spring wheat treated[1/] by aerial application of fungicides to control cereal leaf diseases

	Variety		Bushels/acres Treated	Bushels/acres Untreated	Yield inc
1962	Selkirk	a)	35.9	31.9	4.0
		b)			
1963	Selkirk		25.8	18.3	7.5

[1/]Fungicide treatment - 2 pounds/a zineb in 5 gallons of water.

TABLE 4

1965 - Average yields* of spring and Durum wheat from 3000 acres of leafspot disease control test fields, throughout the State of North Dakota

Variety	Treated[1/] bu/a	Treated[1/] Test wt.	Untreated bu/a	Untreated Test wt.	Increased bu/a
Selkirk (spring)	32.9	56	26.7	56	6.2
Range of yield	26 to 47		16 to 35		
Justin (spring)	29.4	57	25.5	57	3.9
Range of yield	22 to 42		18 to 30		
Wells (Durum)	39.8	58	33.4	57	3.4
Range of yield	23 to 48		19 to 46		

*Date from field tests - 1/2 treated and 1/2 untreated, minimum size 20 acres.

[1/]Fungicide treatment - 2 pounds/a zineb in 5 gallons water, applied by aircraft.

TABLE 5

CEREAL LEAF DISEASE CONTROL EXPERIMENTS, CARRINGTON, NORTH DAKOTA EXPERIMENT STATION 1967

	Variety		bu/a[1]	Test Wheat
Spring Wheat	Chris	Untreated	50.9	60.0
		2 applications[2]	54.8	60.8
		3 applications	56.5	60.0
	Selkirk	Untreated	48.1	58.5
		2 applications	61.8	59.5
		3 applications	63.7	58.8

1/ Average yeild 3 replication, significant 5% level

2/ Treatment 1½ pounds of Dithane M-45 plus spreader sticker

TABLE 6

1969 - Yield of spring wheat treated [1] with fungicide to control leaf disease in Minnesota

Variety	Treated bu/a	Treated T/wt	Untreated bu/a	Untreated T/wt	Yield bu/a Increased
ERA	38.0	58.5	29.1	57.3	8.9

1/ Fungicide treatment - 2 pounds/a Dithane M-45.

TABLE 7

1970 - Yield of Winter Wheat Treated[1/] with Fungicide to Control Leaf Disease in Nebraska

Variety	Treated bu/a	Treated Test wt.	Untreated bu/a	Untreated Test wt.	Yield bu/a Increase
Lancer	71.4	57	60.1	57	11.3
Warrior	71.0	58	63.3	58	7.7

[1/] Fungicide treatment - 2 pounds/a Manzate 200.

ORNAMENTALS.

The Ornamental Industry

The "ornamental" or "environmental" plants industry is an extremely fragmented and complex section of agriculture. To correctly assess the benefits of the EBDC fungicides, one must attempt to integrate this framentation into some sort of an overall framework of industry areas. Flower crops that are produced commercially comprise one such area. These include crops grown in beds for cut flowers (roses, chrysanthemums, carnation, etc.) as well as those grown in pots and sold as complete flowering plants (poinsettias, Easter lilies, etc.). The crops are now grown mainly in greenhouses. In the South they are grown outdoors, perhaps under saran cloth or slatted coverings to protect them slightly from cold or sun.

Two other areas of the ornamental plants industry fall under this "flower crop" area. The production of bedding plants involves many types of flower crops started from seed, transplanted into flats or very small pots, and sold to home gardeners and landscapers for further transplanting into flower beds. Petunias, marigolds, pansies, etc., are common examples. Although they rarely flower, indoor green plants or "tropical foliage plants" are included in the "flower crop" area of the ornamental plants industry as well. This rapidly growing industry includes hundreds of plant types used as large specimen

plants for interior landscapes as well as small potted plants for bedside or tableuses.

It is possible to identify another area of the ornamental plants industry by considering the cold hardy plant material grown for use in the outdoor landscapes of the northern United States. Crops grown for these uses include the herbaceous perennials such as peonies, some ferns, some chrysanthemums, etc. The woody trees and shrubs are the crops most commonly thought of when considering this segment of the industry. The plant diversity here is enormous, including hundreds of different flowering and shade trees, evergreen trees and shrubs, deciduous shrubs, and groundcovers.

One final area that falls within the overall ornamentals picture is that [illegible]ing with the use and maintenance of these plants. It is difficult to ascertain the size of these areas of our industry. It would doubtlessly be extremely large! Landscapers, grounds keepers, and homeowners often have a different view toward management of pests than production segments of the industry. Pest control is a very individualized matter. Within any one landscaper's clientele, there exist persons who insist on adequate prevention of disease and persons who easily tolerate disease occurrence.

General Nature of EBDC Uses

A detailed analysis of the impact of each EBDC ornamental plant registration and use on each of these industry segments will not be attempted in this analysis. To do so would be to get quickly bogged

down into minor details because of the multi-faceted nature of the ornamental plant industries as was pointed out above. The literature used to document disease occurrence and EBDC uses on ornamental plants is cited at the end of this section. Specific reference to the literature at each appropriate place in this discussion will not be attempted. There is a long and diverse use history of EBEC fungicides in the ornamental plant industries. Many of the recommended uses were substantiated from efficacy research and uses first developed for fruit and vegetable problems. The similarity of many ornamental diseases to those found on fruit and vegetable crops has provided needed sources of information for the ornamentalist for many years.

Table 1 lists the registered uses for EBDC fungicides on ornamental plants. Amobam, nabam, and metiram have few or no ornamentals uses r[illegible]ered. In addition, use of these products appears to be practically nil in the industry at this time. Mancozeb is registered for use on 21 hosts for at least 26 diseases. Maneb is registered on 16 hosts for at least 35 diseases. Zineb is registered on 21 hosts for at least 69 diseases. Zineb appears to be the material most broadly registered and labeled for use by all segments of the industry.

A most significant part of the EBDC fungicide use picture in ornamentals is that they can be used to counter the myriad of severe but minor or sporadic disease problems that may come up in a nursery, greenhouse, or ornamental planting. As has been pointed out in earlier sections of this analysis, the EBDC's are relatively

non-phytotoxic, are broad spectrum, are readily available, and are not expensive. Thus, they become the material of choice when an ornamentalist encounters a disease problem. Extension service state specialists have recognized this fact over the years when dealing with protecting an industry from hundreds of diseases on hundreds of plant types. Strate registrations have been developed to bring some of these most essential uses properly onto labels. Table 2 is an example of uses found on a Manzate 200 label developed for the State of Florida by DuPont. Thus, an analysis of the uses of EBDC fungicides on ornamentals must go beyond the Federal registration lists.

It is impossible to list all the EBDC uses in ornamentals; however some of the common flower crop and woody ornamentals uses are listed in Tables 3 and 4. Because of the high value of ornamental cro[illegible] plantings, it is difficult to rank the uses as to importance. All diseases on ornamentals can be serious wherever and whenever they occur, especially in production programs. For instance, mancozeb is used by many rose growers for seven different diseases (Table 4). Black spot is a common and serious disease. For this reason, mancozeb as well as 20 alternative fungicides are registered for control of black spot on roses. On the other hand, downy mildew is one of the most serious diseases a greenhouse rose grower may encounter. It is not common, however, so only zineb and two copper fungicides are registered for use. Clearly, the benefit of the EBDC labels on roses rests as much on the zineb for downy mildew label as on the mancozeb for black spot label!

Major EBDC Uses

Rust diseases are common on many ornamental crops. They can occur anywhere in the nation, but most commonly are found on the West Coast. EBDC fungicides have been used for many years to combat most of these diseases (Table 5). Zineb is the most widely used, but mancozeb is becoming more and more popular. As can be seen from the table, additional labelling needs to be done to get complete coverage of these uses in all states. Anthracnose on shade trees (ash, maples, oaks, sycamores) can be serious in the northeast and north central United States. Preventive spraying of landscape trees is not widely done, however, unless a cool, wet spring occurs (one out of every 4 or 5 years in Ohio). Cedar apple rust is quite serious each year on certain crabapple cultivars in the northern Plains States. Alternaria leaf blight and Fusarium stem rot are common on greenhouse grown carnations in the northern states when the summer is hot. Rose rust is widespread on the West Coast during cool, rainy weather.

We do not have reliable information as to the extent of EBDC usage for these diseases, however. The reasons for this are the diverse nature of the ornamentals industry (as noted earlier), the tendency to use EBDC's for diseases not specifically labeled, and the many products on the market containing one of the EBDC fungicides. For instance, of 354 zineb products currently registered, 58 contain general recommendations for roses on the label (Table 6). It is uncertain how many actually contain specific recommendations for rose rust on the label. A survey of zineb products sold in Ohio revealed

that even the listing of ornamental crops on various labels was not consistent (Table 7). Thus, one cannot obtain data on the extent of usage by an analysis of existing products sales or distribution. The overall benefit of EBDC fungicides in ornamentals is their widespread usefulness on many diseases and the fact that alternative materials are generally not as effective, are themselves subject to RPAR's, are more phytotoxic, are not as widely available, or are more expensive.

There are, however, some rather large volume uses that do bear analysis. EBDC's are used to combat several diseases on flower and foliage crops in the southern states. The warm, humid climate plus outdoor growing guarantee total losses due to disease without protective fungicides.

Mancozeb is currently the material of choice to protect chrysanthemums from *Septoria* leaf spot, *Botrytis*, and *Ascochyta* blight in Florida. Growers there are fortunate to have a label that allows such use in that State (Table 2). On the average across the State, protective fungicides are applied weekly to the mum crop being grown for flowers. Mancozeb would be applied every other week, with either benomyl or chlorothalonil sprayed on alternate weeks to give sufficient control. Two hundred gallons of spray are used per acre for a total of 78 pounds of mancozeb (80 WP) applied per acre over a year's time (1-1/2 lb mancozeb/100 gal X 2 X 26 aplications). Specialists in Florida have estimated current mum production at 900 acres. Therefore, this mancozeb use amounts to about 70,000 lb of mancozeb as 80 WP fungicide.

Added to this chrysanthemum use would be that used on mums being grown for stock. Cuttings are harvested from stock crops in Florida that provide plant material for practically all the growers throughout the United States. Of course, a more intensive disease protection program is practiced here. About 70 mancozeb applications per year are applied over 130 acres of production for a yearly use total of 31,000 lb. Thus, we have a total use picture of mancozeb on mums in Florida of about 100,000 lb.

Chlorothalonil and benomyl are alternative fungicides that could be used. The primary limiting factor is cost. Chlorothalonil costs about 3 times more than mancozeb use and benomyl is about 4 times more expensive. Furthermore, there are phytotoxicity problems with chlorothalonil, especially on the flowers. Finally, it is believed that too much dependency upon benomyl could lead to resistance of the pathogen to that fungicide.

There are 8,100 acres of gladiolus commercially grown outdoors in Florida. For protection against Botrytis and Curvularia blights, mancozeb is sprayed every other week to protect the crop. Again, figuring 3 lb/acre/application, this use would account for 631,000 lbs of mancozeb 80 WP. Benomyl, some coppers, and ferbam are alternatives but are not widely used. Benomyl is too expensive and might lead to resistance. Ferbam is not widely available and leaves an unsightly residue. The coppers can cause plant injury and also leave residues that would make sale of the crop difficult.

The tropical foliage plant industry in Florida has grown rapidly in recent years and is now estimated at $250 million wholesale value, with 75,000 acres in production. Growers utilize chlorothalonil, benomyl, and mancozeb for control of foliar fungal pathogens. Surveys designed to gather information on the total volume of materials used are not yet completed. Mancozeb's wide spectrum of activity is useful for combatting the 8-10 known foliar fungal diseases on each of the over 300 plant types produced. Obviously, need for mancozeb goes far beyond what is specifically outlined on the State label for Florida (Table 2).

Foliage growers use mancozeb at 1 to 1-1/2 lb/100 gallons of water. For greenhouse-grown foliage plants, spray applications are made weekly during the warm and wet months (May to November) and every 1-2 weeks during the cooler, drier months. Where plants are grown out of doors, the applications will be even more frequent. Although precise information is lacking, we estimate that most growers will apply mancozeb about 20 times a year to most stock plants. For many of the plants in finishing areas, mancozeb is used on a less frequent schedule. As plants get closer to sale, sprays are usually discontinued to reduce unsightly residue.

Mancozeb is essential on foliage plants because of broad spectrum disease control, general lack of phytotoxicity, low cost, and wide availability. Furthermore, it has been found that the combination of mancozeb with copper hydroxide is the only spray that will provide satisfactory protection against the several bacterial blights caused

by Xanthomonas. This spray combination is presently specifically labelled for use on philodendron, but is widely needed on other plants because of its essentiality.

Benomyl does not provide sufficient broad spectrum control for general use on foliage plants and may lead to pathogen resistance. Chlorothalonil has a wider control spectrum than benomyl but is injurious to some plant species (most notably schefflera). Both of these alternative fungicides are much more expensive than mancozeb and are not as widely available. Although total mancozeb volume figures are not known, it is clear that its use is extremely beneficial to this large tropical foliage plant industry.

Alternative Fungicides in Ornamentals

Tables 3 and 4 list alternatives that are properly registered for control of the noted diseases. A survey of growers and our review of the limited sales information made available to us leads to the conclusion that the various EBDC fungicides noted in Tables 3 and 4 are preferred to the alternatives in almost all instances. There are serious negative properties possessed by the alternatives which make most of them unsuitable, especially for repeated or routine use. As pointed out earlier, ornamentalists require pesticides that give high levels of disease control because of the high value and major investments required to produce these sorts of crops. Diseases can be serious because they cause death of plants, may cause leafspots or blights which detract from the beauty of the plant and thus lowers

market value. These indirect cosmetic losses are hard to document but are very real in the eyes of an ornamental plant buyer or seller! Along the same lines, many fungicides may themselves cause cosmetic problems. Heavy residues, tissue burning, leaf curling, or other phytotoxic results from fungicides cannot be tolerated in this industry. This is especially true on those which are sold while flowering. Finally, we must again consider that the usefulness of a fungicide on ornmentals often rests in its broad spectrum of disease control on many plant types; control of 1 or 2 diseases on 1 plant type is not of much use to a nurseryman or ornamentalist who is responsible for protecting hundred of plant types against diseases in any one nursery or greenhouse.

Chlorothalonil and benomyl, two commonly listed alternatives in Tables [illegible] and 4, are generally considered to be more efficacious on the diseases mentioned than the EBDC also noted. Why then are they not chosen more often? Chlorothalonil has a very limited ornamentals label. Although it is not generally injurious, chlorothalonil can cause phytotoxicity on such plants as schefflera and chrysanthemums (open flowers). Chlorothalonil is active on many more diseases than those currently listed on the label. Thus, as the label is expanded, more chlorothalonil doubtlessly will be used. Benomyl, on the other hand, is widely labelled for use on many ornamental plants. Its use record is practically free of phytotoxicity problems. Benomyl, however, has a much more restrictive spectrum of control. Many EBDC controled diseases, such as rusts or <u>Alternaria</u> blights or downy mildews, cannot be controlled by benomyl. Further, fungi have a

tendency to develop resistance to benomyl. Finally, cholorothalonil and benomyl are considerably more expensive than EBDC's. This expense is a very real factor in the major volume uses discussed earlier. It is probably of lesser concern than the performance factors mentioned above, however.

Occasionally, captan, cycloheximide, folpet, and dodine are listed as alternative fungicides. Captan and folpet are widely available materials, especially for the yard and home garden market. They are broad spectrum fungicides, but are more expensive and not labelled for as many diseases as the EBDC's. There is no doubt they would be used widely if EBDC uses were curtailed. However, the future of captan and folpet is uncertain and labels are currently not being expanded because both materials are RPAR candidates. Dodine is a fungicide available to commercial users only. It is labelled for use on fruit crops. Ornamental use occurs only where fruit tree genera are sometimes used as ornamentals (peaches, cherries, pecans, etc.). Cycloheximide is primarily labelled and marketed as a turf fungicide, with a very few ornamentals uses on the labels of some cycloheximide products. It is not widely sold for use on ornamentals, mainly due to phytotoxicity problems.

Ziram, thiram, and ferbam are dithiocarbamate fungicides mentioned as alternatives in many cases. Although their degree of effectiveness is not generally as great as the EBDC's and they are apt to be more phytotoxic, more use would be made of these materials if the need arose. They are currently so overshadowed by the EBDC's that

they are not being produced in great quantities and are rarely available to ornamentalists. In addition, it should be mentioned that ferbam leaves an unsightly, intolerable residue on plant material. It certainly could not be used on any flowering or foliage crop near marketing time.

There are several fixed copper fungicides that are registered for many of the diseases listed in Tables 3 and 4. Copper oxychloride, copper quinolinolate, COCS (copper oxychloride sulfate), bordeaux, basic copper sulfate, and copper oleate (for homeowner use only) are mentioned most often. As with fruits and vegetables, the copper fungicides were widely used on ornamentals from the early 1900's to the 1950's when the EBDC's and other organic fungicides were developed. Growers rapidly shifted away from use of copper because of the tendency of coppers to injure plant tissue, especially in cool, overcast, humid weather. In addition, coppers leave a terrible residue on leaves and do not provide the level of disease control achieved with EBDC's. Coppers must still be used on some ornamentals because there is nothing else that provides better protection against bacterial blights caused by <u>Xanthomonas</u>. As was mentioned earlier, the combination of copper fungicide with mancozeb is a very essential use on foliage crops for this reason. However, of all the alternatives listed in Tables 3 and 4, the coppers would probably rank among the <u>least</u> desirable. Many of them are not widely available. The ornamentals registrations were achieved many years ago, often under "me, too" type situations. Thus, efficacy would need to be completely reviewed before they could be widely recommended. They are not

patented materials and it is doubtful that companies would develop a minor crop ornamentals label even if the need were there.

Sulfur is another old fungicide which is labelled for many of the diseases mentioned. As with the coppers, practically no sulfur is used on ornamentals at this time. The fungicide is generally phytotoxic if used when the weather is hot and dry. It leaves a noticable residue, and the efficacy of sulfur for control of many of the listed diseases would be marginal.

Three commonly mentioned alternative fungicides are undergoing the RPAR process or pre-RPAR reviews. These are benomyl, captan, and folpet. The essentiality of affected EBDC uses on ornamentals thus depends upon the outcome of these reviews. Of course, we cannot comment in depth because the review processes are not finished. However, the fact that these materials are being reviewed does emphasize the importance of maintaining the EBDC use.

What is the overall usefulness of the "alternatives" to combat the ornamentals diseases for which EBDC's are currently being used? An examination of many state bulletins produced a list of 283 diseases on 93 ornamental plant hosts. The list is not presented here because it would introduce too much detail. The alarming result of such an analysis is that if ferbam, coppers, and sulfur are discounted as undesirable alternatives, 80% of the EBDC uses would have no other alternative (Table 8). Another 8% would be added if we assume RPAR's or pre-RPAR review materials are lost. Those that do "survive" this

realistic alternative appraisal are listed in Table 9. As was already discussed, many of the alternatives in Table 9 have only a few ornamentals uses on the label (dichloran, dodine, glyodin, oxycarboxin, etc.), have phytotoxicity problems (chlorothalonil, cycloheximide, etc.) or are not widely available (ziram, tributyl tin chloride, etc.). This brings to light the serious upheaval in the existing technology of chemical disease control on ornamental plants if the uses of EBDC fungicides were lost. Table 10 lists plant types for which no adequate fungicide would be available for use, making the same alternatives analysis as before. Such a situation is a serious threat to the survival of all segments of the ornamentals plant industry in the United States.

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3. Fungicide and Nematicide Tests. The American Phytopathological Society, St. Paul, Minnesota. The following reports from 1971 through 1977 give comparative efficacy and phytotoxicity of EBDC's and other fungicides for the diseases mentioned:

Volume 32 (1977)
pp. 134-135 - Hawthorn and crabapple, rust
p. 136 - Dogwood, Septoria leaf spot
p. 140 - Roses, rust
p. 143 - Viburnum, downy mildew
p. 144 - Zinnia, Alternaria blight
p. 145 - Maple, leaf spot

Volume 31 (1976)
p. 134 - Azalea, flower blight
p. 134 - Dogwood, Septoria leaf spot
p. 135 - Fuchsia, rust
pp. 135-136 - Geranium, rust
p. 136 - Hawthorn, leaf spot
p. 136-137 - Viburnum, leaf spot
p. 144 - Hawthorn, rust

Volume 30 (1975)
p. 115 - Rose, black spot

Volume 29 (1974)
p. 103 - Chrysanthemum, flower blight complex
p. 104-105 - Geraniums, rust
p. 105 - Gladiolus, corm rots
p. 107 - Rose, black spot
p. 110 - Rose, rust
pp. 110-111 - Snapdragon, rust
p. 111 - Statice, anthracnose
pp. 111-112 - Statice, Cercospora leaf spot
p. 121 - Azalea, flower blight
p. 124 - Poplar, cutting bed cankers

Volume 28 (1973)
pp. 109-110 - Chrysanthemum, Ascochyta blight
p. 113 - Narcissus, leaf scorch and red blotch
p. 116 - Rose, rust
p. 117 - Rose, blackspot
p. 126 - Crabapple, rust
p. 126 - Hawthorn, rust
p. 127 - Firethorn, scab
p. 128 - Radiata pine, terminal crook
pp. 129-130 - Scotch pine, needlecast

Volume 27 (1972)

pp. 121-122-123	- Chrysanthemum, Ascochyta blight
p. 125	- Narcissus, leaf scorch and red blotch
p. 127	- Rose, black spot
p. 131	- Rose, rust
p. 137	- Radiata pine, pine needle blight

Volume 26 (1971)

p. 112	- Carnation, leaf spot
p. 112	- Chrysanthemum, Ascochyta blight
p. 113	- Dogwood, leaf blight
p. 115	- Laurel, leaf spot
p. 116	- Azalea, flower blight
p. 118	- Rose, rust

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12. Wehlburg, C. et al. 1975. Index of plant diseases in Florida, Bulletin 11, Division of Plant Industry, Florida Dept. of Agriculture and Consumer Services, Gainesville, June, 1975.

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Table 1. EBDC Registrations on Ornamentals

1. Diammonium EBDC (Amobam) - none

2. Disodium EBDC (Nabam) -
   - A. Azalea - petal blight (Ovulinia)
   - B. Camellia - petal blight (Sclerotinia)
   - C. Carnation - anthracnose, leaf spots, rust
   - D. Chrysanthemum - anthracnose, leaf spots, rust
   - E. Snapdragon - anthracnose, leaf spots, rust
   - F. Roses - black spot, powdery mildew

3. Mancozeb -
   - A. Azalea - petal blight
   - B. Camellia - petal blight
   - C. Carnation - leaf spot
   - D. Chrysanthemum - Botrytis blossom blight
   - E. Crabapples - Cedar apple rust, scab
   - F. Dahlias - Botrytis blight
   - G. Dogwood - Anthracnose
   - H. Gladiolus - Botrytis and Curvularia flower and leaf spots
   - I. Holly - Purple spot
   - J. Hollyhock - anthracnose, leaf spot, rust
   - K. Honeysuckle - Herpobasidium blight
   - L. Iris - Didymellina leaf spot
   - M. Lily - Botrytis blight
   - N. Mistletoe - mold
   - O. Pachysandra - Volutella leaf and stem blight
   - P. Pansies - anthracnose
   - Q. Peony - Botrytis and Phytophthora blights
   - R. Rhododendron - petal blights
   - S. Roses - black spot
   - T. Snapdragon - rust
   - U. Tulips - Botrytis blight
   - V. Zinnia - leaf blight

4. Manganese EBDC (Maneb)
   - A. Asters - rust, stem rot
   - B. Azaleas - petal blights
   - C. Camellias - petal blights
   - D. Carnations - Alternaria blight, anthracnose, Botrytis blight
   - E. Chrysanthemums - Ascochyta blight, Botrytis petal spot, Septoria leaf spot
   - F. Dahlias - Alternaria blight, Botrytis blight
   - G. Dogwood - Anthracnose
   - H. Geraniums - Botrytis blight
   - I. Gladiolus - Botrytis blight, Curvularia and Stemphylium leaf spots
   - J. Hydrangeas - Botrytis blight
   - K. Iris - Alternaria blight or leaf spot, Botrytis blight
   - L. Lilies - Botrytis blight
   - M. Pansies - Alternaria blight or leaf spot, anthracnose, Botrytis blight
   - N. Peonies - Alternaria blight or leaf spot, Botrytis blight, Phytophthora blight
   - O. Roses - Black spot, Cercospora leaf spot (Texas), rust (California)
   - P. Snapdragons - Botrytis blight, downy mildew, rust
   - Q. Zinnias - Alternaria blight, Botrytis blight

Table 1 continued

5. Zinc EBDC (Zineb) -
    A. Aster - Botrytis flower blight and stem rot, downy and powdery mildew, leaf spots, rust
    B. Azalea - galls, leaf spots, petal blight
    C. Camellia - petal blight
    D. Carnations - Alternaria blight, anthracnose, Botrytis blight, leaf spots, powdery mildew, Fusarium root rot
    E. Chrysanthemums - Anthracnose, Botrytis blight, leaf spot, rust, Ascochyta ray blight
    F. Cyclamen - Botrytis blight, leaf spot
    G. Dahlias - Botrytis blight, leaf spots, powdery mildew, stem rot, storage rots
    H. Delphinium - Botrytis blight, Cercospora and Septoria leaf spots, powdery mildew, rust, stem rot
    I. English ivy - leaf and stem spots, twig blight
    J. Gladiolus - Alternaria leaf blight, Botrytis gray mold, Curvularia leaf spot, Stemphylium leaf spot
    K. Geraniums - Botrytis gray mold, leaf spot, powdery mildew
    L. Hollyhocks - anthracnose, leaf spots, rust
    M. Hydrangea - Botrytis, leaf spots, powdery mildew rust
    N. Iris - Botrytis leaf blight, Alternaria leaf spot, rust
    O. Lilies - Botrytis gray mold
    P. Pansies - Anthracnose, leaf spot
    Q. Peonies - flower blight
    R. Roses - black spot, Botrytis gray mold, downy and powdery mildews, leaf spots, rust
    S. Snapdragons - anthracnose, Botrytis blight, leaf spots, powdery mildew, rust
    T. Tulips - Botrytis blight
    U. Zinnias - leaf spots

6. Metiram (Polyram)
    A. Roses - black spot

Table 2. Manzate 200 fungicide uses on ornamentals found on a state label for Florida (EPA SLN NO. FL-770008).

Crop	Diseases
Azalea	Cylindrocladium rot Phytophthora, spp
Arborvitae	Cercospora blight
Cedar, Red	Cercospora blight Phomopsis blight
Chrysanthemum	Aschochyta blight
Cordyline	Cercospora leafspot
Dieffenbachia	Leptosphaeria brown spot
Dracaena	Fusarium leafspot
Fern	Rhizoctonia blight
Ficus	Cercospora leafspot
Gladiolus	Botrytis rot Curvularia rot
Juniper	Phomopsis blight
Ligustrum	Cercospora leafspot
Peperomia	Cercospora leafspot
Philodendron	Dactylaria leafspot Phytophthora leafspot
Pleomele	Fusarium leafspot
Schefflera	Alternaria blight
Statice	Cercospora frogeye
Venus Flytrap	Anthracnose

TABLE 3. Common Diseases of Flower Crops in Which EBDC Fungicides* Have Been Recommended for Control.

Crop	Maneb	EBDC Specifically Registered	Registered Alternatives
Aster	Rust	Yes	Ziram, Cu oxychloride
Chrysanthemum	Ascochyta	Yes	Chlorothalonil, Benomyl
	Botrytis Petal Spot	Yes	Captan, Benomyl, Chlorothalonil
Geranium	Rust	No	None
Rose	Blcak Spot	Yes	Many
Snapdragon	Rust	Yes	Ziram
	Zineb		
Aster	Rust	Yes	Cu oxchloride, Ziram
Carnation	Alternaria Leaf Spot and Branch Rot	Yes	Captan, Ferbam, Folpet Cu oxychloride, Copper quinolinolate
	Rust	No	Ziram, Captan, Cu oxychloride
	Greasy Blotch	No	None
Chrysanthemum	Ascochyta Blight	Yes	Chlorothalonil, Benomyl
	Rust	Yes	Ferbam, Sulfur, Cu oxychloride
	Botrytis Petal spot	Yes	Captan, Chlorothalonil, Benomyl
Celosia	Leaf Spots	No	Chlorothalonil (Termil, only)
Columbine	Rust	No	None
Dahlia	Botrytis Blight	Yes	Benomyl, Bordeaux, Ferbam, Basic $CuSO_4$, Dichloran, Thiram
Hollyhock	Rust	Yes	Lime Sulfur, Ferbam, Cu oxychloride
Hydrangea	Leaf Spots	Yes	Ferbam, Sulfur, Benomyl, Chlorothalonil (Termil, only)
Impatiens	Leaf Spots	No	Chlorothalonil (Termil, only), Benomyl
Lily	Botrytis Blight	Yes	Benomyl, Bordeaux, Basic $CuSO_4$
Marigold	Leaf Spots	No	Chlorothalonil (Termil, only), Basic $CuSO_4$
Nasturtium	Leaf Spots	No	Chlorothalonil (Termil, only), COCS, Basic $CuSO_4$
Pansy	Anthracnose	Yes	Cu oxychloride
	Leaf Spots	Yes	None
	Scab	No	None
Peony	Botrytis Blight	Yes	Benomyl, Bordeaux, Cu oxychloride, Basic $CuSO_4$, Ferbam
	Leaf Spots	No	Cu oxychloride, Basic $CuSO_4$
Phlox	Leaf Spots	No	Cu oxychloride, Basic $CuSO_4$ Sulfur
Rose	Black Spot	Yes	Many

(continued)

Table 3 (continued).

Crop	Zineb	EBDC Specifically Registered	Registered Alternatives
Snapdragon	Rust	Yes	Ziram, Cu oxychloride, Sulfur
	Anthracnose	Yes	Captan, Cu oxychloride, Ferbam, Folpet
	Downy Mildew	Yes	Cu oxychloride
Stock	Leaf Spots	No	Cu oxychloride, Basic $CuSO_4$
Sweet Pea	Anthracnose	No	Cu oxychloride
	Leaf Spots	No	Basic $CuSO_4$, Ferbam
	Mancozeb		
Aster	Downy Mildew	No	None
	Alternaria Blight	No	Basic $CuSO_4$
	Botrytis Blight	No	Chlorothalonil (Termil, only) Benomyl
Carnations	Alteraria Leaf Spots	Yes	Captan, Ferbam, Folpet, Cu oxychloride, Copper quinolinate
Chrysanthemum	Ascochyta Blight	No	Chlorothalonil, Benomyl
	Botrytis Blight	Yes	Captan, Chlorothalonil, Benomyl
Dahlia	Botrytis Blight	Yes	Benomyl
Geranium	Botrytis Blight	No	Benomyl, Chlorothalonil
	Rust	No	None
Gladiolus	Botrytis Blight	Yes	Benomyl
	Leaf Spots	Yes	Ferbam, Basic $CuSO_4$, Bordeaux
Hollyhock	Leaf Spots	Yes	Bordeaux, Cu oxychloride, Basic $CuSO_4$, Ferbam
	Rust	Yes	Lime Sulfur, Ferbam, Cu oxychloride
Lily	Botrytis Blight	Yes	Benomyl, Bordeaux, Basic $CuSO_4$, Ferbam, Cu oxychloride
Petunia	Botrytis Blight	No	Benomyl, Chlorithalonil (Termil)
Snapdragon	Rust	Yes	Ziram, Cu oxychloride, Sulfur
Statice	Anthracnose	No	None
Tulips	Botrytis Blight	Yes	Benomyl, Bordeaus, Basic $CuSO_4$, Thiram, Ferbam
Zinnia	Alternaria Blight	Yes	Cu oxychloride, Folpet

*Based on references listed at the end of the narrative.

Table 4. Common Woody Ornamentals Diseases in Which EBDC Fungicides Have Been Recommended for Control*.

Crop	Mancozeb	EBDC Specifically Registered	Registered Alternative
European horse chestnut	Leaf Blotch	No	Lime sulphur (Dormant)
	Leaf Spot	Yes	Benomyl
Camellia	Flower Blight	Yes	Captan, Ferbam, PCNB
Hornbeam	Leaf Spots (v)	No	None
Hickory	Leaf Spot	Yes	None
Catalpa	Leaf Spot	No	None
Hackberry	Leaf Spot	No	None
Redbud	Leaf Spot	No	None
Fringetree	Leaf Spot	No	Benomyl, Basic $CuSO_4$
Virgin's bower	Leaf Spot and Stem Rot	No	Sulphur, Benomyl
Dogwood	Leaf Spots	Yes	Bordeaux, Basic $CuSO_4$, Benomyl
Cotoneaster	Leaf Spot	No	Basic $CuSO_4$, Benomyl
Hawthorn	Leaf Blight	No	Actidione
	Rusts	No	Sulphur
	Scab	No	None
Bush honeysuckle	Leaf Spot	No	Basic $CuSO_4$, Benomyl
Eleagnus	Leaf Spot	No	None
Euonymus	Anthracnose	No	Benomyl, Lime sulphur (Dormant)
Beech	Leaf Spot	No	None
Forsythia	Leaf Spot	No	Basic $CuSO_4$
Franklinia	Leaf Spot	No	None
Coffee Tree	Leaf Spot	No	None
Witch Hazel	Leaf Spot	No	Basic $CuSO_4$, Benomyl
Winterberry	Tar Spots	No	None
	Leaf Spots	No	Basic $CuSO_4$
Larch	Needle Rusts	No	Lime Sulphur (Dormant)
Privet	Leaf Spot	No	Basic $CuSO_4$, Bordeaux, Benomyl
Honeysuckle	Leaf Blight	Yes	None
Magnolia	Leaf Spot	No	PCNB
Flowering Crabapple	Rust	Yes	None
	Scab	Yes	Benomyl, Folpet
	Bitter Rot	Yes	Folpet
	Sooty Blotch	Yes	Folpet
Pachysandra terminalis	Twig Blight	Yes	None
Boston Ivy	Leaf Spot	No	Cu oxychloride, Bordeaux
Princess Tree	Leaf Spot	No	Benomyl, Lime Sulphur
Mock Orange	Leaf Spot	No	Basic $CuSO_4$, Benomyl
Cherry Laurel	Leaf Spot	No	Basic $CuSO_4$, Sulphur
Ornamental peach	Leaf Curl	Yes	Ziram, Ferbam, Lime Sulphur, Captafol, Dodine, Coppers (Several)
Flowering Japanese cherries	Witch's Broom	No	None
Oak	Leaf Blister	No	Basic $CuSO_4$
	Leaf Spot	No	Bordeaux
Azalea	Azalea Petal Blight	Yes	Benomyl, Ferbam, Ziram, Thiram, PCNB, Captan, Diclone
	Azalea Leaf Spot	Yes	Benomyl, Ferbam, Basic $CuSO_4$

(continued)

Table 4 continued.

Crop	Mancozeb	EBDC Specifically Registered	Registered Alternative
Azalea (continued)	Dieback	No	None
	Leaf Spots	No	Bordeaux, Basic $CuSO_4$, Benomyl
	Rhododendron Petal Blight	Yes	Benomyl
Rose	Black Spot	Yes	Many
	Leaf Spot	Yes	Coppers, Benomyl, Sulphur
	Brown Canker	No	Basic $CuSO_4$, Lime Sulphur, Sulphur
	Brand Canker	No	None
	Common Stem Canker	No	None
	Crown Canker	No	None
	Cane Blight Canker	No	None
	Alternaria Leaf Spot	No	Copper Quinolinolate
	Downy Mildew	No	Basic $CuSO_4$, Cu oxychloride
Mountain Ash	Leaf Rusts	No	None
	Scab	No	None
Lilac	Phytophthora Blight	No	None
Viburnum	Downy Mildew	No	None
	Maneb		
Maples	Leaf Blister	No	None
Camellia	Flower Blight	Yes	Captan, Ferbam, PCNB
Dogwood	Leaf Spots	Yes	Bordeaux, Basic $CuSO_4$, Benomyl
Hazelnuts	Leaf Curl	No	Lime Sulphur (Dormant)
Pinus	Needle Cast	Yes	Chlorothalonil
	Brown Spot	Yes	None
White Pine	Fusiform Rust	Yes	None
Rose	Black Spot	Yes	Many
	Leaf Spot	Yes	Coppers, Benomyl, Sulphur
	Rust	Yes	Coppers, Ferbam, Actidione, Glyodin Sulphur
	Cercospora Leaf Blight	Yes	None
	Zineb		
Maples	Leaf Spot; Purple Eye	No	Bordeaux, Basic $CuSO_4$
European horse chestnut	Leaf Spot	Yes	Lime Sulphur (Dormant)
Amelanchier (serviceberry)	Rust	No	None
Boxwood	Rusts	No	Lime Sulphur (Dormant)
Hickory	Leaf Spot	Yes	None
Flowering Quince	Rust	Yes	None
	Leaf Spots	Yes	Benomyl, Basic $CuSO_4$
Dogwood	Flower and Leaf Blight	Yes	Benomyl
	Leaf Spots	Yes	Benomyl, Basic $CuSO_4$, Bordeaux
Hawthorn	Leaf Blight	No	Actidione
	Rusts	No	None
	Leaf Spot	Yes	None
Euonymus	Leaf Spot	Yes	Benomyl, $CuSO_4$

(continued)

Table 4 continued.

Crop	Zineb	EBDC Specifically Registered	Registered Alternative
Ash	Leaf Spot	No	None
English Ivy	Stem Spot	Yes	None
	Twig Blight	Yes	None
Butternut	Brown Leaf Spot	No	None
Japanese Walnut	Yellow Leaf Blotch	No	Benomyl, Dodine
Mountain laurel	Leaf Spot	No	Ferbam, Basic $CuSO_4$, Benomyl
	Blight	No	Bordeaux
Flowering crab-apple	Rust	Yes	None
	Frog-eye Leaf Spot	Yes	None
White Pine	Southern Cane Rust	No	Ferbam
Oak	Anthracnose	Yes	Bordeaux, COCS, Benomyl, Lime Sulphur
Azalea	Azalea Petal Blight	Yes	Many
	Azalea Gall	Yes	Cu oxychloride
	Leaf Scorch	Yes	Basic $CuSO_4$
	Rust	No	None
	Azalea Leaf Spot	Yes	Ferbam, Benomyl, Coppers
Flowering Currant and gooseberries	Leaf Spots	Yes	Ferbam, Folpet, Benomyl, Captan
Rose	Botrytis Blight	Yes	Many
	Leaf Spot	Yes	Many
	Rust	Yes	Many
	Downy Mildew	Yes	Basic $CuSO_4$, Cu oxychloride
Willow	Gray Scab	No	None
	Leaf Spot	No	None
Lilac	Leaf Spot	Yes	Benomyl, Basic $CuSO_4$, Bordeaux
Hemlock	Blister Rust	No	None
	Needle Rust	No	Lime Sulphur (Dormant)
Periwinkle	Blight	No	Benomyl
Pinus	Leaf Casts	No	None

* Based on references listed at the end of the narrative.

TABLE 5. EBDC Fungicide Uses to Control Rusts on Ornamentals.*

Plant	EBDC Specifically Registered	Alternatives
Almond, Flowering	None	Ferbam
Ash	None	None
Aster	Mancozeb, Zineb	Sulfur
Azalea	None	Ferbam
Birch	None	None
Carnation	Nabam	Captan, Ferbam, Folpet, Oxycarboxin, Sulfur Cycloheximide
Cedar, Red	None	None
Cherry, Flowering	None	None
Cherry, Laurel	None	None
Cherry, Plum	None	None
Chrysanthemum	Nabam, Zineb	Ferbam, Sulfur
Crabapple	None	Sulfur
Delphinium	Zineb	None
Dieffenbachia	None	None
Fuchsia	None	None
Geranium	None	Ferbam
Hawthorn	None	Sulfur
Hollyhock	Mancozeb, Zineb	Sulfur
Hydrangea	Zineb	None
Iris	Zineb	None
Juniper	None	Ferbam
Mayday Tree	None	None
Mountain Ash	None	None
Peach, Ornamental	None	None
Pear, Ornamental	None	None
Plum, Ornamental	None	None
Poplar	None	None
Quince	None	None
Rhododendron	None	None
Rose	Zineb	Ferbam, Sulfur, Cycloheximide Tributyltin Chloride
Service Berry	None	None
Snapdragon	Mancozeb, Maneb, Zineb	Ferbam, Sulfur, Folpet, Glyodin
Willow	None	None

*Based on references listed at the end of the narrative.

TABLE 6. Number of Products Containing EBDC Fungicide and Their Relationship to Rose Uses.*

	Total Products	Total Registered on Roses	Total Combination Products Registered on Roses
Amobam	2	0	0
Nabam	51	0	0
Mancozeb	110	18	5
Maneb	306	34	9
Zineb	354	58	34
Metiram (Polyram)	53	3	0

*Taken from EPA Label Microfiche File, 10/77.

TABLE 7. Labelled Ornamental Uses of Zineb Products Sold in Ohio.*

Product	Package Size	Crops on Label
FMC Zineb 72 WP	50 lb.	Azaleas, camellias, carnations, chrysanthemums, hollyhocks, snapdragons gladiolus, roses, fruits, and vegetables.
E-Z Flo Vega-guard	50 lb.	Vegetables only.
Science Zineb	8 oz.	Azaleas, camellias, gladiolus, snapdragons, chrysanthemums, carnations, hollyhocks, roses.
Rockland Zineb	8 oz.	Asters, carnations, iris, pansy, zinnia, dahlia, hydrangea, peony, geranium, lily, snapdragon, gladiolus, tulips.
Tobacco States Zineb	1 lb.	Snapdragons, chrysanthemums, carnations, hollyhocks.
Acme Zineb	8 oz.	Same as Science Zineb.

*As determined from labels on file in the offices of the Plant Industry Division, Ohio Department of Agriculture.

Table 8. An analysis of fungicides that might serve as alternatives to 283 EBDC uses on 93 ornamental host plants.*

	Number of Uses	% of Total
1) Benomyl - Only alternative listed	15	5
One of alternatives	151	53
2) RPAR or pre-RPAR Materials -		
Only alternatives listed	22	8
3) Ferbam, coppers, or sulphur -		
Only alternatives listed	188	66
4) No alternatives listed	38	13
5) Total of Numbers 2, 3, 4	248	88

* Master list of hosts and diseases provided by Biochemicals Department, E. I. DuPont de Nemours and Co. (Inc.), Wilmington, Delaware, December, 1977. Alternatives derived from the EPA Label Microfiche.

TABLE 9. EBDC ornamentals uses which have an alternative; excluding ferbam, coppers, sulfur, RPAR'd materials or pre-RPAR review materials.*

Plant	Disease	Alternative
African violet	Botrytis Blight	Chlorothalonil (Termil)
Begonia	Botrytis Blight	Chlorothalonil (Termil)
Camellia	Flower Blight	Ziram
Carnation	Rust	Oxycarboxin
	Botrytis	Chlorothalonil (Termil)
Chrysanthemum	Leaf Spots	Chlorothalonil, Ziram
	Ascochyta Ray Blight	Chlorothalonil
	Botrytis Blight	Chlorothalonil, Dichloran
Geranium	Botrytis Blight	Chlorothalonil, Dichloran
Gladiolus	Botrytis Leaf Spot	Ziram, Dichloran
	Corm Decay	Thiram
Iris	Leaf Spots	Chlorothalonil
Lily	Gray Mold (Botrytis)	Chlorothalonil
	Bulb Rot	Thiram
Petunia	Botrytis Blight	Chlorothalonil (Termil)
Rose	Diplocarpon Black Spot	Chlorothalonil, Dodine, Lime Sulfur, Glyodin, Tributyltin Chloride, Anilazine, Ziram
	Rust	Cycloheximide, Glyodin, Tributyltin Chloride
	Leaf Spots	Chlorothalonil, Cycloheximide
Snapdragon	Botrytis Gray Mold	Chlorothalonil
Tulip	Bulb Decay	Thiram
Azalea	Ovulinia Petal Blight	Thiram
Conifers	Lophodermium Needle Cast	Chlorothalonil
Hawthorn	Leaf Blight	Cycloheximide
	Leaf Spots	Cycloheximide
Hydrangea	Botrytis Bud Blight	Dichloran, Chlorothalonil (Termil)
Juniper	Rust	Cycloheximide
Pecan, Ornamental	Scab	Dodine, Triphenyltin
	Leaf Spots	Dodine, Triphenyltin
	Powdery Mildew	Triphenyltin, Dodine
	Leaf Blotch and Scorch	Dodine, Triphenyltin
	Anthracnose	Dodine, Triphenyltin
	Spot Anthracnose	Dodine, Triphenyltin
Pine	Scirrhia (Brown Spot) (Needle Blight)	Chlorothalonil
	Lophodermium Needle Cast	Chlorothalonil
Rhododendron	Leaf Spots	Ferbam, Ziram
Sycamore	Anthracnose	Dodine
Walnut	Anthracnose	Chlorothalonis, Dodine, Thiram
	Leaf Spots	Dodine
	Yellow Leaf Blotch	Dodine
	Blights	Dodine

*See Table 8 for sources of information.

Table 10. Ornamental plants for which no fungicides would be available for foliar disease control if EBDC's were lost and coppers, ferbam, sulphur, RPAR'd and pre-RPAR review chemicals were not available.*

Plant	Number of Diseases Involving EBDC Uses
Almond, Flowering	5
Amaryllis	3
Ash	3
Aster	4
Aucuba	1
Barberry	1
Birch	2
Boxelder	6
Boxwood	3
Buckeye	3
Butternut	3
Buttonwood	3
Caladium	2
Cedar-red	1
Cherry, Flowering	6
Cherry Laurel	5
Clematis	1
Cotoneaster	1
Crabapple	5
Currant (Alpine)	2
Cyclamen	2
Daffodil	2
Dahlia	3
Daisy (Shasta)	2
Dieffenbachia	1
Dogwood	5
Elm	4
Euonymus	2
Fir	3
Forsythia	1
Fuchsia	1
Gardenia	1
Hickory	4
Holly	6
Hollyhock	3
Honey Locust	2
Honeysuckle	1
Horsechestnut	3
Hyacinth	2
Ivy	3
Kinnikinnik (Arctostaphylos)	1
Linden	1
Maple	6
Mayday Tree	5
Mimosa	1
Mountain Ash	4
Mulberry	1
Narcissus	3
Oak	4

(continued)

Table 10 continued.

Plant	Number of Diseases Involving EBDC Uses
Peach, Ornamental	5
Pear, Ornamental	3
Pachysandra	3
Pansy	4
Peony	4
Philodendron	1
Photinia	1
Plum, Ornamental	5
Poplar	2
Privet	1
Pyracantha	1
Quince	3
Redbud	2
Service Berry	1
Shrubs	1
Snowball	2
Spirea	1
Sumac	1
Violet	1
Virginia Creeper	1
Willow	6
Zinnia	2

* See Table 8 for sources of information.

Turfgrass

Further information on fungicide efficacy and alternatives may be obtained from American Phytopathological Society, Fungicide, and Nematicide Test Reports, Volumes 26-32, turfgrass fungicide sections.

Uses

Turfgrasses have become the major ground cover plant for most of the suburban and urban United States. Home grounds, school grounds, parks, golf courses, athletic fields, and institutional and industrial grounds all utilize turfgrasses for erosion control, playing surfaces and aesthetic improvement. For most purposes the desired end result is a unif[illegible] living green carpet. Standards of quality have been constantly rising for all turfgrass purposes with home lawns, athletic fields and golf courses receiving special emphasis (15).

The importance of disease control in turfgrass culture has increased concurrently with the rising quality standards. Intense usage of these turf areas due to the leisure time recreation explosion has necessitated comprehensive disease control practices which include fungicide treatment. For example, it is estimated that there are in excess of 14,000 golf courses in the United States. The States of Ohio and Pennsylvania each has in excess of 600 courses. Fungicides are used on tees, greens, and fairways for control of fungus induced diseases.

In a similar manner athletic fields and home lawns are receiving the brunt of the outdoor recreation boom. Disease control is an essential part of the quality maintenance program for most athletic fields and many home lawns.

Important diseses of turfgrass include those caused by the *Helminthosporium* species. These fungi are responsible for leaf lesions (spots and blighting), crown rots, and root rots. Various names have been given to these diseases such as Melting out, Leaf spot, and Helminthosporium leaf spot. Almost every turfgrass species is attacked, including Kentucky bluegrass (*Poa pratensis*), annual bluegrass (*Poa annua*), fescues (*Festuca sp.*), bentgrasses (*Agrostis sp.*), rye grasses (*Lolium perenne*), Bermuda grass (*Cynodon sp.*), and Zoysia (*Zoysia sp.*). The Helminthosporia are major pathogens for most of these grass species throughout the United States (10).

The *Rhizoctonia* fungi also incite foliar blighting and crown rots of most of the above grasses. Popularly known as Brown patch or Rhizoctonia brown patch these diseases are especially severe under the humid conditions of the southeast, east, and midwestern United States (10).

Pythium fungi attack seedling turfgrasses as well as established plantings. Bentgrasses and rye grasses are especially susceptible. In addition to foliar blighting, crowns, roots, and stolons may be killed. Pythium blight is known to turfgrass managers as cottony blight, grease spot, and Pythium. It is perhaps the most severe of

all turfgrass diseases resulting in death of large areas of grass when environmental conditions are favorable for disease spread. Pythium blight is a severe problem in the southern, Mid-Atlantic and midwestern areas of the United States (10).

Maneb, mancozeb, and a lesser amount of zineb are among the major fungicides used throughout the United States for control of the *Helminthosporium* pathogen. Smaller amounts are used for *Rhizoctonia* and *Pythium* diseases. It is estimated that 650,000 lb. of these materials are used in the United States primarily for these three disease groups. The largest single use is estimated to be for *Helminthosporium* control. This use estimate was obtained by extrapolation from manufacturers' data, distributor sales, and individual salesmen's data for given areas. The maneb volume is estimated at 390,000 lb., mancozeb at 230,000 lb., and zineb at 30,000 lb. used for turfgrass. Most formulations are wettable powders containing 70-80% a.i. and are applied as sprays with a water diluent.

The maneb and mancozeb products are highly effective against the *Helminthosporium* diseases. They are the lowest cost fungicides available for the turf usage both in terms of price per pound as well as in price per unit area of turfgrass treated. Treatment rates range from 4 to 8 oz. of formulated product per 1,000 sq. ft. for mancozeb, from 3 to 8 oz. for maneb, and 2 oz. per 1,000 sq. ft. for zineb (1, 10).

EBDC fungicide usage on turfgrasses will vary with the diseases to be controlled, the geographic location, and weather situation.

Total number of EBDC applications in one growing season may range from one to ten. It is not possible to compute a meaningful average for either number of applications or dosage on a regional or nationwide basis. Turfgrass disease control programs are influenced by numerous factors such as turf quality standard to be maintained, pathogens and diseases present, disease severity, temperature, rainfall and humidity, grass variety and grass maintenance program. For the northeastern and midwestern U. S. the golf course use of EBDC materials might consist of 1-3 treatments during April and May for *Helminthosporium* diseases and 2-4 treatments in July and August for *Rhizoctonia*, *Pythium*, and *Helminthosporium*.

Economic Losses from Turfgrass Diseases in the Absence of Satisfactory Disease Control

Turf diseases result in loss of playing surface quality on golf courses and athletic fields and in loss of satisfactory aesthetic appearance of home lawns and other landscape grounds. The loss or damage to landscape quality from turfgrass disease is difficult to evaluate in monetary terms. The damage represents a detriment to the satisfactions derived from home grounds and their care. Turfgrass disease losses on athletic or recreational turfgrass areas such as golf courses represent an economic monetary loss. Of greatest significance is the potential disruption of the use of such facilities.

The sports of golf, lawn bowling, grass court tennis, football and others require a uniform grass playing surface. Turfgrass disease with resultant play surface damage can and does result in loss of clientele from golf courses, resort hotels and various vacation complexes. In one instance in the 1970-72 period severe turfgrass disease losses due to managerial incompetence at a New Jersey vacation resort golf course resulted in a drastic drop in the volume of business to the point of near bankruptcy (H. Cole, personal observation). In 1977 at a Pocono mountain resort, severe turfgrass disease during a midsummer period resulted in decreased use of other resort facilities and a drop in room occupancy rates (H. Cole).

It is difficult to ascertain whether the total volume of business in a resort area decreases or whether redistribution to other locations occurs. It is believed that the situation may be analogous to the absence of snow at ski resorts. Quality golf courses provide a basis for the development of recreational businesses and employment of large numbers of people in auxiliary enterprises.

Alternative to EBDC Fungicides

Effective alternatives to the EBDC compounds are available and are used by turfgrass managers to varying extents depending on the material and diseases to be controlled. The alternatives are from 2-5 times more costly than the EBDC materials when used at equivalent rates to obtain similar levels of efficacy (Table 1) (1,3,4,12,13,17,18).

Fungicide resistance to many of the currently available turfgrass fungicides is present in native populations of turfgrass fungal pathogens including Helminthosporium, Rhizoctonia and Sclerotinia. Fungicide resistance is believed to arise through natural mutation followed by fungicide selection pressure that allows the more resistant individuals in a population to survive and reproduce. Continuous use of a single fungicide allows a fungal population to be subjected to selection pressure in one direction. If one resistant individual is present in a population of several million or billions of individuals the fungicide selection pressure will competitively favor the resistant individual. Depending on reproductive rates after varying numbers of generations, the resistant individual will have become the predominant portion of the population to the exclusion of others. If various fungicides of different modes of action are used, the likelihood of resistance occurring is much reduced. Different fungicides may be used as combinations in tank mixes, in alternating schedules, or even in alternating years. Prevention of unidirectional shifts in pathogen population composition is the long-range goal in fungicide management (5,6,7,8,9,14,16,19,20).

The only way currently available to prevent development of fungicide resistance is through availability and use of as wide as possible an array of fungicides with different mechanisms of action. At present chlorothalonil (Daconil 2787®), Anilizine (Dyrene®), cycloheximide (Actidione®) are the only three other fungicides with a degree of activity against Helminthosporium. Fungicide resist- problems presently exist in control of this pathogen. The loss of

EBDC materials would accentuate fungicide resistance problems by increasing selection pressure for survival of strains resistant to the three alternatives (5).

Rhizoctonia is recognized for resistance selection. Alternative registered products include benomyl (Tersan® 1991), Cyclo-heximide-PCNB (Actidione RZ®), thiophanate methyl (Fungo®) thiophanate ethyl (CL 3336®, Bromosan®, Spectro®), anili-zine, (Dyrene®), Chlorothalonil (Daconil 2787®), thiram, and mercury. Resistant strains are present for many of the alternative materials. A large number of different fungicides should be main-tained (H. Cole, unpublished data). Summer use of mercury fungicides will be canceled with the end of the 1978 season. Benomyl, thio-phanate methyl and ethyl, and PCNB have all been placed on RPAR noti-fication. Hence, a situation which already has control problems would be come even more severe if, or when, four more of the remaining mate-rials would no longer be available.

Pythium is a variable fungus. The mancozeb and zineb products can provide low cost suppression when used preventively and when used incidently for control of other turfgrass diseases. Much of the maneb and mancozeb treatments as used for Helminthosporium control also provides a large measure of Pythium suppression. If these materials are no longer available then far more numerous and more severe Pythium outbreaks are anticipated. Alternate fungicides for Pythium control are 3-5 times more costly than the EBDC's (Table 1). The three

presently available alternatives, chloroneb (Tersan sp.®), ethazole (Koban®), and Dexon® are only effective against the _Pythium_ diseases and have no other turfgrass uses.

For further information in the fungicide resistance area the reader is referred to "Symposium on Resistance of Plant Pathogens to Chemicals," J. D. Gilpatrick, Chairman. Proc. Amer. Phytopathological Soc. 3: 47-98. 1976.

Control of turfgrass disease is far more efficient when the user can select from a variety of fungicides. This is true whether chemical application is the primary basis for a control program or an integrated pest management approach is used. In fact it is even more important to have a wide array of materials available for use with integrated control programs. This allows the use of the one material most compatible with the grass cultivars and ecosystem present at the specific location. In addition it may be concluded that total pesticide usage will be less when a larger number of different materials are available than when only a single material can be used. For example, if a number of different fungicides are available then a specific material can be chosen which is most suited to the specific pathogens, grasses, and environment in which they interact.

TABLE 1. Comparison of fungicide costs for EBDC materials vs. alternative products.

Fungicide product	Primary* Diseases Controlled	Dosabe Range** in oz per 1,000 sq. ft.	List Price*** per oz to User	Cost per 1,000 sq. ft.
EBDC Materials				
Tersan LSR 80w	H, BP	3-8	8¢	24-64¢
Fore 80w, Mancozeb, M-45 80w,	H, BP, P	4-8	8-14¢	32-112¢
Dithane Z 78 75w	H, P	2	9¢	18¢
Alternative materials				
Daconil 6F & 75w	H, BP	206	22¢	44-132¢
Dyrene 50w	H, BP	4-6	18¢	72-108¢
Actidione RZ	H, BP	1-2	31¢	31-62¢
Tersan SP 65w	P	4	38¢	152¢
Koban 50w	P	4-8	66¢	264-528¢
Tersan 1991 50w	BP	2	61¢	122¢
Fungo 50w	BP	2	62¢	124¢
CL 3336 50w	BP	2	58¢	116¢
Thiram 75w	BP	3-6	13¢	39-78¢
Spectro	H, BP, P	3-4	29¢	87-116¢
Bromosan	BP	3-6	28¢	84-168¢
Dexon 35w	P	4-6	28¢	112-168¢

* H = Helminthosporium diseases

BP = Rhizoctonia Brown Patch

P = Pythium Blight

** from EPA registered labels

*** Average retail list prices - compiled by H. Cole, Jr., from current catalogue listings (see ref. 2)

Grass Seed

Grass establishment in the United States is accomplished mainly through seeding. Grass seed is produced for planting of erosion control, ground covers, home lawns, and recreational areas such as athletic fields and golf courses. Other major purposes of grass seed are for planting of pastures, rangelands, and forage and hay crops. The large majority of turfgrass and other grass seed production is concentrated in Washington and Oregon. It is estimated that 270,000 acres of grass seed production fields were maintained in Washington and Oregon in 1977. Control of foliage, culm, and crown diseases is crucial to successful seed production. It is estimated that 50,000 acres of bluegrasses and ryegrasses for grass seed production were sprayed with the maneb and maneb plus nickel sulfate fungicides in 1977 for control of stem rust, strip rust, leaf rust (Puccinia sp.) (11).

The maneb materials are formulated as wettable powders. Two to four sprays per growing season may be applied depending on disease severity. These are applied at the rate of 1.6 to 2.4 lb./acre of active ingredient in 500-100 gallons of water/acre.

Economic Losses in the Absence of Satisfactory Disease Control

Diseases of seed production plantings result in reduced seed yields. In addition to rust disease losses in the seed fields certain

other fungal diseases may occur. The full significance of these other pathogens such as the Helminthosporium spp is not completely known. Control of diseases in seed production fields may minimize the necessity for future control of seed-borne diseases in the newly established planting. In this manner, fungicide use in seed fields may result in lesser total fungicide use than if the plantings were established with diseased seed or seed bearing pathogen propagules.

In 1976 and 1977 in Washington and Oregon, grass seed yields ranged from 400-1000 lb./acre where maneb treatments were applied. Without maneb, seed yields were 100-300 lb./acre (11, Dr. John R. Hardison); the rust diseases were primarily responsible for these losses.

Alternative Control Practices and Fungicides

The basic disease control practice for several decades had been open burning of residual straw, stubble, and debris after seed harvest-to eliminate survival and buildup of disease organisms including potential seed borne pathogens. The advent of environmental legislation regarding air pollution from smoke and combustion odors is gradually eliminating burning as a disease control practice. The alternative to after-harvest burning is the use of fungicides at regular intervals during the production season. Seed growers are shifting towards fungicide use. The EBDC fungicides represent the only economically feasible fungicides for Helminthosporium and other fungi normally

controlled by open burning. In addition to the disease situation induced by the prohibition against burning crop residues there are rust diseases which cause severe losses in yield whether burning is practiced or not. When rust diseases occur, the maneb and maneb plus nickle sulfate fungicides are used for rust control in addition to burning. Assuming an average seed price to growers of 40¢/lb. and production costs of $170.00/acre average it can readily be seen that growers must produce 425 lb. of seed/acre to break even. Without the use of maneb the seed crop cannot be profitably produced in areas with foliar disease problems. As the use of open burning of stubble residue declines it is anticipated that the demand for maneb for foliar disease control of seed production plantings will increase.

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Forestry

The EBDC fungicides include the six fungicides: amobam, mancozeb, maneb, nabam, metiram (Polyram), and zineb. All of these except amobam and metiram are registered for use on forest products.

The average individual would probably assume that a fungicide registered for use on a particular tree species would be used on vast forested acreages for control of a particular disease. The forest industry, however, does not consider it economically feasible to apply protectant fungicides to forest stands. Consequently, the bulk of EBDC fungicides used by the forest industry are applied to products other than forest stands.

The largest quantity of EBDC fungicide used on a forest product is formulated in slimicides and used by the pulp and paper industry.

The 690 pulp and papers mills in the United States produce 48.4 million tons of pulp per year and apply 8,000 tons a.i. of slimicide

each year to control slime (primarily bacteria and fungi) in the wet end of their mills. If all slimicides used were those that contain nabam, approximately 600 to 2,000 tons of nabam would be used annually by U. S. pulp and paper mills.

Although some mills have discontinued the use of EBDC containing slimicides, others continue to use such materials. The actual quantities of nabam used by pulp and paper mills are considered to be a trade secret and consequently, there are no reports of the quantity used. Alternate slimicide formulations that do not contain nabam are either more expensive or are less effective. If those formulations were used exclusively there would be an increased cost of pulp and paper products to the American consumer. Although there are 45 chemicals registered for use in slimicide formulations, a total ban of EBDC-containing slimicides would, undoubtedly, lead to a build up of slime resistant to the alternate slimicide and create a greater need for research and development of new slimicides ingredients. This would cause an increase in the price of paper even if no new slimicides were developed.

The average pulp and paper mill purges about 30 million gallons of water effluent from its system each day and replenishes with fresh water. Slimicide is added daily as good manufacturing practice demands. Some mills use more slimicide than others because they follow the toxin rather than the biochem method of slime control. The latter method allows some slime to build up in the system which reduces the amount of extractives in the water effluent but the reduced slimicide

cost may offset the loss of extractives. The chemical industry of the United States obtains large quantities of chemical extractives from pulp and paper mill effluents and, consequently, this industry is dependent upon quality control within mill effluents. A ban of EBDC-containing slimicides would change the quality of slime in effluents) (dependent upon which alternate slimicide were used) and alter the quality and quantity of extractives in effluents. Such changes could be devastating to chemical plants if the extractives on which their livelihood depended were removed or degraded by the microorganisms within slime.

Maneb and mancozeb are used to control needle cast of Christmas tree plantings in several lake states including Michigan and Wisconsin. Christmas tree growers in 17 states reported the use of Maneb or Mancozeb on 10,000 acres of Christmas trees valued at $35,000,000. This amounts to 2.2% of the 450,000 acres of Christmas trees in the United States actually sprayed with an EBDC fungicide. The Christmas tree industry uses about 15,000 lb of maneb each year. This information is based on an assumed average of 400 trees per acre sprayed with an average volume of one quart/tree/application and 10 applications per year with 1-1/2 lb. maneb per 100 gallons. Bravo is a registered substitute fungicide but it cost about 3 times that of maneb. A ban of EBDC fungicides would increase the cost of Christmas tree production approximately $3.60 per acre, but the quality of the trees produced with the alternate fungicide would be reduced and further decrease the value of the final product. A reduced value of $1/tree

would consequently increase the cost of Christmas tree production approximately $404/acre.

A very small amount of maneb is used to control herpobasidium blight of honeysuckle in wind barrier plantings in the Plains states (8 lb./year; 4 applications/year) and a minor amount of EBDC fungicides (maneb, zineb, mancozeb) is used in forest tree nurseries to control a number of foliar diseases on several tree species. Thirty-seven nurseries in 17 northern states reported the use of maneb to control needle cast of pine species. Maneb is used in numerous nurseries throughout the United States to control anthracnose and leaf spot diseases of several hardwood species. There are 190 forest tree nurseries in the United States which have 9,209 acres of land available for seedling production. Regeneration of all forest tree species is dependent upon seedlings produced in these 190 nurseries and if a fungicide is not registered or available for use in a particular nursery during a critical time interval of a month or two, an entire tree species may be lost for reforestation purposes leaving hundreds of acres of forest land denuded for the additional twelve months needed to produce the next year's seedling crop. Such idle acres would probably need additional site preparation to control weeds. Such additional expense would magnify in the forest product economic chain: the land owner would pass the increased cost to the buyer, the buyer would sell the lumber, pulp, paper, etc., to the manufacturer at a higher cost, the manufacturer would sell to the wholesale distributor at a higher cost, and the consumer would ultimately absorb the several mark ups. Although there are 9,209 acres in forest tree

nurseries on which trees may be grown, less than half that acreage is planted to seedlings each year. Assuming a need for 10 sprays each year on 4,000 acres of seedlings would create a market for 6,000 lbs of maneb per year at a cost of $10,200. A substitute fungicide costing 3 times that of maneb would create a market for $30,600 of the other fungicide (a net increase of $5.10/acre of seedlings).

Thus, the impact of a ban of all EBDC fungicides in the United States would add to the nation's spiraling inflation rate principally through an increased cost in paper and other products derived from pulp and paper mills. Christmas tree and nursery seedling crops would not be seriously damaged by such a ban of EBDC fungicides unless the substitute fungicides were also banned. A ban of all fungicides for use on all forest products would seriously cripple our nation. A lack of slime control in paper mills would essentially curtail the production of all paper products.

The risk of use of EBDC fungicides on forest products must be considered minimal if any real risk exists at all. EBDC fungicide residues degrade rapidly in the environment, do not magnify in the food chain, and do not accumulate in water, soil, air, plants, or animals. Their use on forest products seldom contact food or feed and the tolerance of 3 ppm on paper products contacting food should rarely be reached or exceeded.

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